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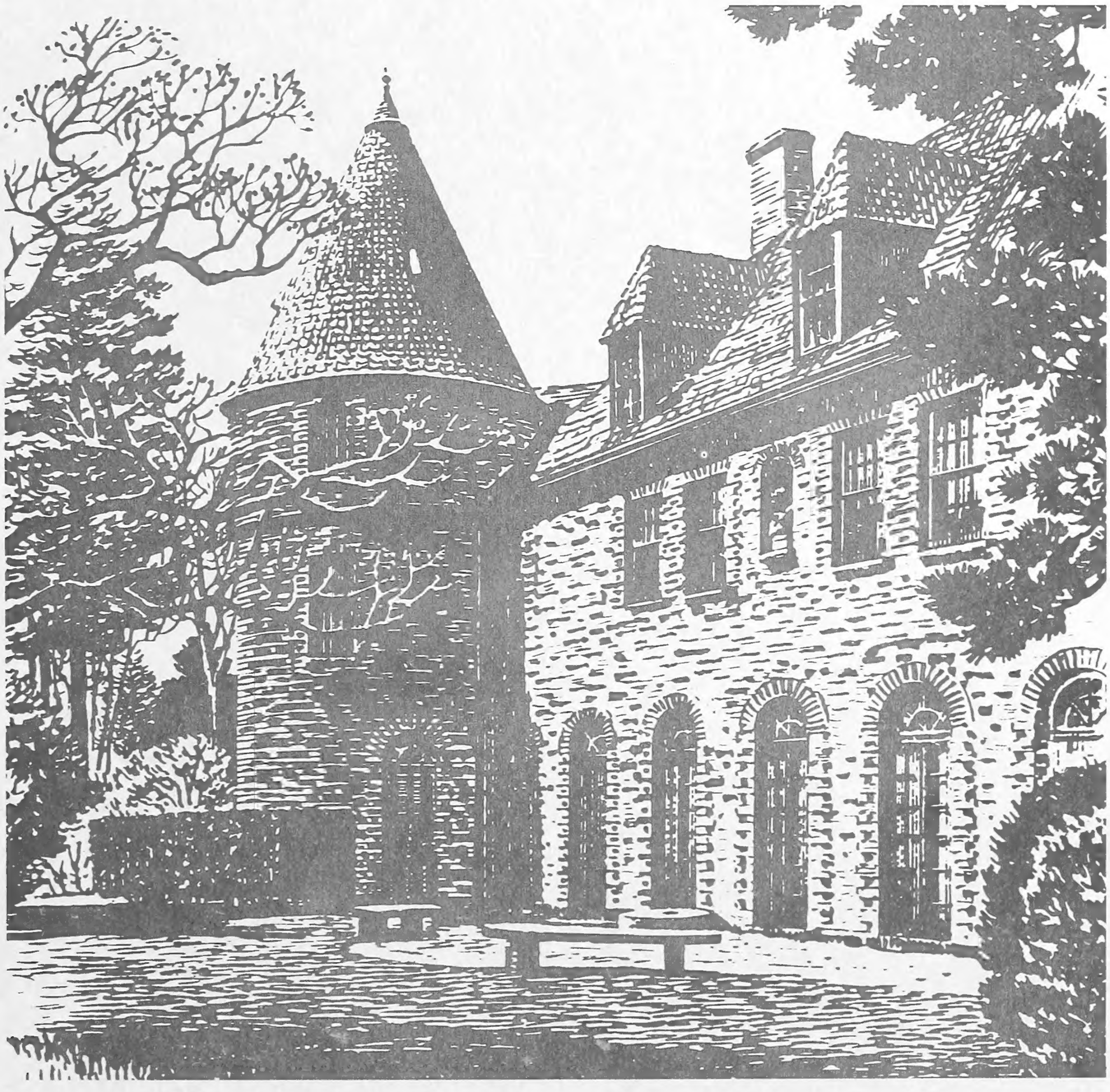
The Pinchot Institute for Conservation Studies

Proceedings for Integrated Pest Management Colloquium

U.S. Department of Agriculture
Forest Service
General Technical Report WO-14



PROCEEDINGS

for

INTEGRATED PEST MANAGEMENT

COLLOQUIUM

October 17-18, 1978

Grey Towers
Milford, Pennsylvania

Edited by

Robert D. Gale
Policy Analysis Staff
USDA, Forest Service

General Technical Report WO-14

March 1979

PREFACE

On October 17 and 18, 1978, the United States Department of Agriculture, Forest Service's Policy Analysis Staff and the Pinchot Institute for Conservation Studies conducted a joint, national colloquium to provide a foundation for a subsequent exhaustive evaluation of Forest Service pest management policies, programs and practices. Twenty-three university and government scientists with particular expertise in various aspects of pest management participated in the conference.

Each contributor is responsible for the accuracy and style of his paper. Statements of the contributors from outside the U.S. Department of Agriculture may not necessarily reflect the policy of the Department.

This colloquium marks the beginning of an extensive evaluation of Forest Service pest management activities. The colloquium focused on the state of the art and issues in integrated forest pest management. It is believed to be one of the first to do so. Information and ideas generated are being used to develop specifications for evaluations by contracting firms of Forest Service programs in insect and disease pest management and in vegetation control.

The colloquium was held at Grey Towers, Milford, Pennsylvania. Grey Towers, a National Historic Landmark, is the former estate of Gifford Pinchot, pioneer conservationist, first Chief of the U.S. Forest Service and twice Governor of Pennsylvania. It is now headquarters of the Pinchot Institute for Conservations Studies.

There was general feeling by those who attended the colloquium that not only were the stated objectives of the meeting achieved but a bond of friendship and trust was established as well. This additional element of confidence should help to facilitate pest management evaluation in the future.

For additional information on this colloquium or extra copies of these proceedings please contact either of the following:

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Integrated Forest Pest Management Colloquium
Pinchot Institute for Conservation Studies
Forest Service, USDA
Grey Towers, Milford, Pennsylvania
October 17 and 18, 1978

Agenda

October 17

9:30 a.m.	Registration Coffee and informal mixing	
10:00 a.m.	Tour Tour of Grey Towers Mansion and grounds. Interpreter-Curator Tour Guide	 John Denne Debbie Fogarty
10:30 a.m.	Opening of Colloquium (conference room) Welcoming remarks	 John Gray, Director, Pinchot Institute - Moderator
10:35 a.m.	Objectives Introductory comments and colloquium objectives	 Robert Gale, Forest Service
10:45 a.m.	Keynote Speaker	John Barber, Forest Service
11:00 a.m.	Forest Service Activities in Pest Management What is the function of each of the Forest Service units which are involved in pest management and how are they interrelated?	 James Stewart, Forest Service
11:20 a.m.	Forest Chemical Controls and EPA Role A discussion of the status of chemicals for forest and related land use. An explanation of the role of EPA in addressing health concerns as they relate to forest pest management.	 Charles Reese, Environmental Protection Agency
11:45 a.m.	Luncheon at Grey Towers	
1:00 p.m.	Alternative Control Techniques A presentation of alternative methods for controlling pests in forest and related lands. Speakers will address specific areas of pest management.	

1:00 p.m.--Range--Charles Scifres, Texas A&M
1:20 p.m.--Rights-of-way--William Niering, Conn. College
1:40 p.m.--Timber vegetation--Mason Carter, Purdue
2:00 p.m.--Timber I&D--David Wood and William Waters, University of California at Berkeley

2:20 p.m.	Integrated Forest Pest Management An explanation of what it is, why it is needed, and how it might be implemented. Ron Stark, University of Idaho
3:00 p.m.	Coffee break
3:30 p.m.	Economics of Pest Management Speakers will address such areas as the importance of resource values, rising treatment cost, potentials to decrease cost through IPM, cost sharing, and the use of probability and risk. 3:30 p.m.--Lloyd Irland, State of Maine 3:50 p.m.--Gerald Carlson, North Carolina State
4:10 p.m.	Analysis and Discussion Models These presentations will summarize the state of existing models, how they can help, and their use in long term management. Speakers will also attempt to identify some opportunities for extending agriculture and insect and disease models to use in forest vegetation management situations. 4:10 p.m.--Albert Stage, Forest Service 4:30 p.m.--Carlton Newton, Univ. of Vermont
6:00 p.m.	Hospitality gathering at Mount Haven Informal discussions and getting acquainted
October 18	Moderator--Everett Towle, Director of Policy Analysis, FS
8:30 a.m.	Forest Service Evaluation of Pest Management A presentation and discussion of the Forest Service's evaluation of its pest management activities. Robert Gale, Forest Service
9:30 a.m.	Discussion The final session of the meeting will consist of a panel, with audience participation, to discuss the previous day's presentations; develop a list of current issues; and to discuss opportunities for the Forest Service evaluation to address the listed issues. Panel Everett Towle, FS - Chairman Barry Flamm, USDA David Ketcham, USDA Robert Gale, FS James Stewart, FS
12:00 Noon	Adjournment

Colloquium Participants

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OBJECTIVES OF THE COLLOQUIUM

Robert D. Gale

I would like to first thank all of you for your interest and willingness to participate in this colloquium. I realize that the relatively short notice several of you received meant some sacrifice on your part.

Many meetings have been held recently to address various facets of integrated pest management (IPM). However, I believe this is the first to address integrated forest pest management in a total context. The majority of IPM meetings have dealt with agriculture crops. Those meetings which have been concerned with forest pests have generally addressed some specific aspect of pest management, such as insect modeling. I would also like to point out that to date little attention has been given to the application of the IPM concept for managing herbaceous pests.

We have organized the colloquium as part of the beginning of an evaluation of Forest Service pest management activities. Three objectives have been identified:

1) to solicit information concerning the state-of-the-art in forest pest management;
2) to review the Forest Service's proposed approach to evaluating their pest management programs; and
3) to identify and clarify the current issues in pest management.

The information obtained here will be assembled in the form of proceedings. They will be made available to all participants and to those who will be involved in the evaluation. It is our goal to have the proceedings out by November 30.

The colloquium has been organized to accomplish the three objectives. Today will consist of several short presentations on assigned topics which we feel are particularly germane to our evaluation. A limited amount of time has been allowed for discussion. The second day is less structured and is intended to foster a free flow of ideas. The colloquium is not a forum to air all sides of all issues. The speakers are considered to be experts in their assigned subject matter, and there should not be a need to spend a great deal of time debating their viewpoint. But rather, our interest is to summarize and clarify. On the other hand, concerning the second day's speaker (myself) and the panel--feel free to cross-examine them.

As I have expressed to most of you personally, WE--the Forest Service--ARE HERE TO LISTEN and to learn. So, let's begin.

KEYNOTE ADDRESS

John C. Barber

Welcome to the Pinchot Institute for Conservation Studies. Dr. John Gray, the Institute's Director, has provided you with a packet including brochures on the Institute's program, and on the history of the estate and the people who have lived here. I hope you will take a few minutes to read these; I think you will find them interesting.

Rex Resler wanted to be here but, in the absence of the Chief and others attending the World Forestry Congress, he had to stay in Washington because of aotions taking place on several critical activities.

I don't really have a keynote speech because I want this to be an open discussion. I'll try to provide only a bit of perspective, but no direction or guidance.

This is our first opportunity to use the Pinchot Institute for Conservation Studies in the way envisioned by President Kennedy in his 1963 dedication address. We hope that this colloquium will establish this building and these grounds as "neutral ground" where issues can be freely presented and discussed.

The Forest Service has delegated authority for the prevention and control of forest insects and diseases on all forest lands: all forest ownerships in the country. We handle pest management directly on the National Forests with Forest Service personnel and Forest Service funds. On other Federal lands we work in cooperation with the managing agencies providing whatever assistance they need and transferring the money to them to carry out the practices on their lands. On the non-Federal public lands and on private lands, pest management is carried out in cooperation with the State Forester or, in some few states, another State Official who has the responsibility for pest management activities. So overall, when it comes to forests and related lands, the Forest Service has the delegated Federal responsibility in the insect and disease management field. At this colloquium we also have to keep in mind that, when we talk about pest management, we have weeds or undesirable plants that are pests as well as insects, diseases, nematodes, etc.

The Forest Service operates in what we consider an environmentally sensitive arena. If you've been involved in the 2,4,5-T situation, as I have during the past 6 to 8 months, you are familiar with some of the sensitivities that are there. We are observed by many "interest groups" because we manage public lands. Our policy on public involvement provides a mechanism for groups to take on the Forest Service...to challenge us in our pest management activities

because we operate on public lands, challenges which are not cast against people who are operating on private lands. On one hand the Forest Service is a very small user of pesticides when you compare forestry use with agricultural use. In that sense, we are not major pesticide users. On the other hand, I think the Forest Service symbolizes for the public the Government's attitude in its approach to dealing with pest management problems. We are concerned to a high degree with public lands in contrast to agriculture where activity is all on private lands, thus the public focus on our pest management problems.

This means that in the Forest Service we cannot be narrow in our viewpoint; we cannot be insensitive to public concerns, and we certainly cannot be complacent when it comes to exploring opportunities in pest management. We have to be an aggressive organization and a progressive organization in dealing with the whole area of pest management.

This colloquium is timely because of the various things that have been happening in the past year or two in the general area of use of pesticides and integrated pest management (IPM). There certainly has been over the last several years an increasing concern expressed by the public for the use of pesticides. Last February we had a symposium which aired the various facets and concerns regarding the use of herbicides in forestry. The proceedings will be out in December. We've also seen in the last year some rather successful conclusions of studies on particular insect problems. For example, the Douglas-fir tussock moth where the accelerated effort concluded substantial research, and we now have a virus registered for control--I think a fine conclusion. We've seen a lot of progress in some of the other efforts--gypsy moth and the southern pine beetle program still underway. A new initiative has been started in cooperation with Canada on spruce budworm. We have a demonstration area on the Front Range in Colorado, outside Boulder, in which the Forest Service, the Colorado Forest Service, the local governments, and the private landowners are working together in a project to control and manage the mountain pine beetle. We are only at the end of the first year of the program, but at this point it looks like a highly successful opportunity to deal with the pest with an integrated pest management approach.

If anyone has any questions about the magnitude of insect problems from a forestry viewpoint, he should look at the "Western Forest Insect Issues Study" which displays the total timber losses on National Forest lands caused by insects in the West. The magnitude of loss attributable to bark beetle is appalling; we're talking in terms of billions of board feet of timber standing dead in the West due to the insect attack.

The pathologists are going to jump all over me because I have emphasized the insects, but the disease impact is a little more difficult to define. Dwarf mistletoe has a substantial impact on growth and stand vigor, and certainly diseases contribute to epidemic insect attacks at various points in time. So we can't talk just about insects or diseases, we have to keep everything in a total perspective.

In agriculture we've seen similar IPM activities during recent years that have been successful. Examples that come to mind are the screwworm problem that was dealt with fairly successfully and the pilot efforts on boll weevil and some of the cotton insects. The Department of Agriculture has a position that in agriculture and forestry we will move toward integrated pest management--it being the logical means of effective pest management.

We have been asked to do a rather thorough and complete evaluation of Forest Service pest management programs. Bob Gale referred to contracts that will be let to do this job. We hope that this colloquium will help us to define the framework of that evaluation so that we can make it as effective as possible. As we look at the evaluation, we have to keep in mind that pest management is an emotional issue and, consequently, it is a politically sensitive issue; we should keep that in the proper context. We must have a very thorough evaluation--it has to be done in such a manner that the person or persons carrying out the evaluations aren't tagged as being spokesmen for the Forest Service or spokesmen for any interest group--they have to be people who have credibility across the board.

Our experience has shown that when we have a good objective evaluation of our programs it is a learning process, and from this process we identify opportunities to improve our programs. We will be looking for those opportunities to improve our programs following this evaluation. Your presence here today will, I hope, stimulate objectivity in looking at this problem. It certainly will be an opportunity for us to strengthen the learning process. We want you to present and discuss the various facets of pest management. We want your ideas on how we can achieve the best evaluation of our Forest Service pest management efforts--I should say Forest Service and related pest management efforts. We want to identify the critical issues that we should deal with in the evaluation so that we can bring it to a successful conclusion.

Thank you, John Gray, for inviting us to Grey Towers. I appreciate the opportunity to have this national colloquium as a part of the program of Pinchot Institute for Conservation Studies.

FOREST SERVICE ACTIVITIES IN PEST MANAGEMENT

James L. Stewart

In the Forest Service, insect and disease management is handled differently than weed or vegetative competition management. I will first discuss insect and disease management.

The authority to protect trees and forests from insects and diseases is contained in Section 5 of the Cooperative Forestry Assistance Act of 1978 (P.L. 95-313). Previous to October 1, 1978, this authority was granted in the Forest Pest Control Act of 1947 (P.L. 80-110).

The administration of this Act (P.L. 95-313) is delegated to the Chief of the Forest Service. In the Washington Office under the Deputy Chief for State and Private Forestry is a Forest Insect and Disease Management (FI&DM) staff group which provides technical leadership and direction for all phases of the insect and disease management program. A similar staff group exists at the Regional/Area field offices.

The delegated authority of the Act gives the Chief the responsibility to carry out whatever he deems necessary to prevent, retard, control, or suppress incipient, potential, threatening, or emergency insect and disease problems. This responsibility is direct on all National Forest System lands, and cooperatively through respective Federal departments on other Federal lands and through the State Forester or equivalent State official on all State and private lands.

<u>The FI&DM staff groups</u> consist primarily of entomologists, pathologists, and pesticide-use specialists. At the field level the primary functions are to : (1) provide technical assistance and training to Federal land managers and technical support to State entomologists and pathologists; (2) conduct surveys and evaluations to determine forest stand susceptibility to insects and diseases and to determine current and potential impacts of these pests; (3) recommend methods which are biologically sound, environmentally acceptable, and economically efficient to prevent or suppress damaging populations; (4) help conduct suppression projects; and (5) monitor suppression projects to insure proper execution. In addition these groups conduct pilot projects to test operational feasibility of new and improved pest management techniques and strategies.

It is the policy of the Forest Service to use the most effective, economically efficient, and environmentally acceptable control technology available. A question we would ask of the reviewers is how well we are performing in this area. Is this policy adequate?

As research provides information on the interrelations between pests and forest stand conditions, it is also our policy to use this information to the fullest extent possible considering economics and other forest management constraints.

All forest insect and disease suppression projects receive intensive evaluations and reviews before they are approved. They must pass criteria which include: biological evaluations to determine the need for suppression, environmental evaluations to determine the environmental impacts of the pest without control, and the impacts of the proposed suppression methods; a benefit-cost analyses which must demonstrate that the proposed action is cost-effective; and in the case of cooperative projects on State and private lands, there must be a statement that demonstrates a justifiable Federal participation.

Are these criteria adequate? What other evaluations should we be using in our decisionmaking process? Is the Federal role appropriate, as specified?

With the exception of dwarf mistletoe, all suppression projects exceeding $10,000 are reviewed and approved in the Chief's office. Dwarf mistletoe projects, because of their ongoing nature, are approved by the Regional Forester. Is this delegation of authority appropriate? Should the Washington Office take back the dwarf mistletoe approval authority? Should the Regional Foresters/Area Directors have greater authority to approve projects for other pests?

The majority of FI&DM funds for suppression are held in contingency by OMB. Funds are requested from this contingency on a project-by-project basis. When such requests are made, all project proposal documentation is reviewed not only in the Chief's office but also in the Secretary's office and in OMB. These multiple review layers have added weeks to the approval process. They also remove the on-the-ground professionals (entomologists, pathologists, and foresters) far from the decisionmaking. Is this appropriate? Is there a better way?

As an example of how we approach control which includes prevention and suppression, I will briefly discuss the mountain pine beetle. However, we hope the reviewers look at our approach to several pests. Are we depending too much on a single method such as spraying? Are we giving enough emphasis to prevention?

The mountain pine beetle is a spectacular and damaging insect of pines in the West. It kills millions of trees during epidemic years and these dead trees adversely impact esthetics, fire hazard, and wildlife habitat in addition to reducing usable wood volume. Our approach to control for many years has been to fight the epidemic.

The preferred alternative has been to salvage infested trees and remove them from the forest before the beetles can emerge and infest new trees. Where markets or lack of access precludes salvage operations, the infested trees have been cut and burned or cut and sprinkled with an insecticide if fire conditions do not permit burning. This integrated approach is still used to reduce beetle populations and the need will continue where stands are in a susceptible state. Research has now shown that overstocking and overmaturity are contributing causes to beetle outbreaks. Therefore, Forest Service emphasis has shifted to encouraging increased forest management to lessen stand susceptibility.

Control of Unwanted Vegetation. Intensive forest and range management requires that desirable tree or grass species be given competitive advantage over competing vegetation. Also, noxious weeds on rangelands must be controlled as must vegetation that interferes with right-of-way maintenance.

The Forest Service does not have a specific staff group responsible for all technical and staff aspects of unwanted vegetation control. Instead noxious range plants are handled by Range Management, competing vegetation by Timber Management, and rights-of-way by Engineering. FI&DM does provide technical expertise and assistance with respect to pesticide use.

There is no established standard criteria within the decisionmaking process for controlling unwanted vegetation. An exception to this is when the use of 2,4,5-T is proposed. Should there be? Are guidelines adequate? Does the Forest Service have sufficient expertise in weed management on its staffs? These are some of the questions we hope the reviewers will comment on.

Forest Service research on pest management is administered through the office of the Deputy Chief for Research with staff assistance in the Forest Insect and Disease Research Staff. Authority for this research until 1978 was given under the McSweeny-McNary Act, May 22, 1928 (45 Stat. 699, as amended; 16 U.S.C. 581). In 1978, this authority was updated and expanded in the Forest and Rangeland Renewable Resources Research Act of 1978, P.L. 95-307.

The mission of Forest pest research is to provide the knowledge and technology to:

1. define, measure, and evaluate the impacts of destructive pests on forest resources, and on wood in storage and use;

2. detect, assess, and predict changes in the occurrence of these pests; and

3. reduce the numbers and impacts of pests to tolerable levels

by means of control techniques and management strategies that are ecologically sound, economically practical, and environmentally acceptable.

Both formal and informal mechanisms are used to achieve communication between research and the users. These include such things as: yearly coordination meetings between insect and disease research projects and respective FI&DM groups and other users, formal review of the research work unit's 5-year charter (RWUD), joint efforts, and many informal contacts. Once a research item is identified to have application potential, the researcher and FI&DM work closely to accomplish the technology transfer. Are these and the other mechanisms sufficient?

Current insect and disease research is strongly oriented toward developing comprehensive pest management systems including prevention for major forest insects and diseases. Examples would be registration of microbial control agents for the gypsy moth and Douglas-fir tussock moth, work in the West and the South leading to silvicultural techniques to prevent bark beetle outbreaks, development of silvicultural guidelines, and decisionmaking models for dwarf mistletoe, and development of guidelines for root rots.

Research on the eastern and western spruce budworms was recently accelerated through a joint Canada/U.S. Spruce Budworms Program called CANUSA. The mission of CANUSA is to design and evaluate management strategies for control of spruce budworms and/or management of budworm susceptible forests.

In these and all research programs in forest pest research we seek active cooperation of university and industry cooperators. This includes cooperative aid agreements and grants whereby the Forest Service provides funds for cooperative research of interest to all parties involved.

Time does not permit the full listing of the over 40 research work units and the over 150 scientists that are conducting research in the Forest Service on management of insect and disease pests. Approximately 35 percent of this research can be directly tied to what may be called systems research or development of improved pest management strategies. In a broad sense, the remaining research can be indirectly tied to the goal of eventually developing pest management strategies for an array of economically important pests. There are eight Research Work Units and 12 scientists doing research on direct and related aspects of controlling unwanted vegetation.

We ask the reviewers to comment on the appropriateness of our research programs with respect to pest management's priority needs.

Pesticide Use Procedure on the National Forest. Now let me discuss the procedure we have developed for prescribing and controlling the use of all pesticides on National Forest lands.

First of all, a survey is made to determine whether or not control is needed. For example, in reforestation activities a survey is made of the site both before and after planting. A decision that release of a plantation from vegetative competition is made on the basis of scientifically determined requirements and silvicultural guides for the crop tree species. The District Ranger then makes a determination as to the best method of control from all of the possible alternatives--such as manual, mechanical, chemical, or biological. He uses policy manuals, guidelines, research findings, and past silvicultural training to help him with the decision. In the case of insects or diseases, the FI&DM staff group provides additional technical assistance.

It is Forest Service policy to use only EPA registered pesticides in strict accordance with the label and with FIFRA as amended. It is also Forest Service policy to use pesticides only after it has been clearly demonstrated that their use is necessary to meet resource management objectives including environmental protection. If a decision is made to use pesticides, a pesticide-use proposal is prepared and sent to the Forest Supervisor for review. The review team usually includes multidisciplinary resource specialists in such fields as wildlife, recreation, timber, water, and soils. At times, the entire review team makes visits to the proposed treatment area. Recommendations to the Forest Supervisor reflect the total team effort to critically analyze the situation.

A consolidated pesticide-use proposal for all anticipated projects is then submitted by the Forest Supervisor to the Regional Forester. For emergency or unforecasted control needs, pesticide-use proposals can be submitted at any time. The Regional office checks these proposals for their technical correctness and makes recommendations to the Region's full Pesticide-use Coordinating Committee. Again, the interdisciplinary approach is used. The committee usually includes representatives of land management planning, office of information, lands, timber, fire, recreation, wildlife, water, soils, and engineering. This committee makes a recommendation to the Regional Forester for approval or disapproval. With the exception of 2,4,5-T and related TCDD containing pesticides, the Regional Forester has been delegated the authority to approve pesticide uses. In the case of 2,4,5-T and related TCDD containing compounds, the Assistant Secretary for Conservation, Research, and Education has reserved the authority for approval.

The approval of a pesticide-use proposal means only that the staff group concerned is now authorized to process the proposal according to the requirements of the National Environmental Policy Act (NEPA). It does not mean that pesticide applications can start.

Each area or group of similar areas proposed for treatment requires an environmental impact statement or an environmental assessment report designed to carefully consider environmental impacts and provide for State, public, and other agency review.

In virtually every operational control program involving the use of pesticides, an environmental impact statement, either site specific or programmatic, is prepared by an interdisciplinary team, according to NEPA guidelines. Thus, the NEPA document is an integral part of the decisionmaing process.

I want to conclude by saying we look forward to a thorough review--one that will point out where we can improve and alter our approaches, our strategies, our operational aspects, our staffing, our delegations of authority, and our decisionmaking processes in a positive way.

EVOLUTION OF PEST MANAGEMENT

Charles D. Reese

Integrated pest management (IPM) is a rubric under which many forms of pest control may be classified. It would be a mistake to consider IPM and pesticide use as two poles on a continuum. Rather, the poles are prescribed pest management practices versus programmed (i.e., automatic) pest management practices (the latter usually being the exclusive use of chemical agents).

A concise definition of IPM is that given by Dr. Michael Way (Outlook in Agriculture, 1977): "... the balanced use of such measures, cultural, biological and chemical, as are most appropriate to a particular situation in the light of careful study of all factors involved." The concept implies that control measures are used that are in keeping with sound ecological and economic principles to the extent that these can be determined. In addition to the variety of control measures themselves, IPM in practice also includes the crucial components of biological monitoring, population assessment, forecasting and projection of losses. The intention of IPM is to provide the most effective tools for successful management of ecosystems, which will at the same time be least damaging to beneficial organisms, least likely to create resistant strains of target organisms or to induce secondary outbreaks of nontarget pests, while protecting human health and general environmental quality.

While the objectives of IPM is simply better management the potential benefits are considerable, including (a) reduction of pesticide use, (b) reduction of operating costs, (c) the maintenance or increase of yields (including those of non-target quantities), and (d) reduction in variability of yields.

The programmed use of pesticides is often for preventive reasons in circumstances that might allow for some minimum tolerable level of pest infestation. With the exception of the fox in the henhouse or the rabbit in your backyard garden, a pest is a pest because it occurs in numbers. In other words, pest problems are <u>population</u> problems. It follows that pest management is population management, using the same principles as fisheries management and wildlife management. A population becomes a pest problem if it becomes numerous enough to cause significant injury. (The term "significant injury" must, of course, be defined according to the values applied to the particular system being managed). It becomes numerous in two ways: reproduction and immigration; it becomes less numerous through mortality and emigration. Those four terms summarize the main concerns of population ecologists and pest managers: to reduce a population's numbers, you seek to lower reproduction and/or immigration rates, or to raise mortality and/or emigration rates. Everything else is detail (i.e., how you do it!).

Having defined pest management as population management places the origins of pest management clearly among the practitioners and developers of biological control.

Biological control as a concept and a practice may be said to be the progenitor of pest management because of its population orientation. If pests are pests because of numbers, natural enemies are effective when they accurately regulate the pest's numbers, (i.e., "tracking" the pest population, never letting it get too high nor letting it go to local extinction) which would, of course, lead to the extinction of the natural enemy population. Biological control researchers have been in the forefront in the development of basic understanding of population processes and have actively promoted the concept of population management as the key to ecologically sound pest control.

As pesticide development led to new compounds with reduced residual time and occasionally specificity of activity, practitioners of biological control were able to address situations where "pure" biological control methods appeared inadequate. The combined use of pesticides and natural enemies came to be known as integrated control. It involves tactics such as careful timing of the pesticide application to maximize the effect on the natural enemy, or taking advantage of differences in pesticide resistance between the two species. Here we see the blending together of two control tools--pesticides and natural enemies--in a carefully designed combination to manage the pest population.

Those of you familiar with some of the work in biological and integrated control will recognize that most of the work discussed above was concerned with insects, and there is no question that we owe a great debt to a number of fine entomologists for their pioneering efforts in the theory and practice of pest management. However, we should also take note of the development of effective management tools in the fields of plant pathology, nematology, and weed science as well. These include detailed study of conditions for infection by plant pathogens; soil management and crop rotation for control of nematodes, soil-borne pathogens, and weeds; breeding of resistant and tolerant varieties; and, of course, careful population and epidemiology studies of pest species.

The successful adoption and blending of these techniques in an appropriate concept constitutes an integrated pest management program. In order to encourage the adoption of integrated pest management (IPM) techniques as an active component in farm management strategy the successful demonstration of IPM efficacy and availability is required. If market imperfections do not allow for optimal allocation of resources the Federal government can, and has, introduced a series of incentives such as tax breaks and subsides (negative and positive incentives), which would modify the behavior of economic agents so social welfare can be increased while minimizing the private cost.

In spite of a sizeable body of literature which cites the private and public benefits which accrue as a result of IPM practices, IPM still represents an insignificant portion of the crop protection effort. Thus, given market imperfections, it is likely that some kind of intervention by Federal agencies will be required if IPM is to take an increasingly large foothold.

These programs would be aimed at:

1) generating the necessary data base;
2) remedying the technical knowledge gaps;
3) providing hazard issurance to IPM users;
4) and establishing training opportunities to improve pest management skill levels.

To support IPM activities, EPA has established an IPM unit. The OPP/IPM group is organizing IPM knowledge and resources within EPA, and maintaining linkages with other agencies and institutions. Other agencies have identified an IPM representative who can work closely with EPA. This OPP/IPM unit will continue to evaluate EPA organization needs, and sustain the IPM incentive initiative through management of the core support projects.

We see a cooperative venture with you in carrying out the ongoing and projected projects. These initiatives are necessary in carrying out our responsibilities to: (1) IPM input to the RPAR process, (2) shepherding and expediting of the registration of biological pesticides, (3) dissemination of IPM information, and (4) oversight of EPA/R&D projects related to IPM.

INTEGRATED BRUSH MANAGEMENT SYSTEMS FOR RANGELAND:
Conceptual Utility and Practical Applications

C. J. Scifres

Effective range management involves the implementation of a series of interrelated management activities to achieve specific management goals. Vegetation manipulation to minimize the influence of undesirable plant populations is only one activity in the series of steps toward optimizing productivity of range resources. The primary requisite for successful range management is sound grazing management. The potential effectiveness of all other activities in the management strategy hinges on proper grazing use--grazing at the appropriate time(s) with the right kind(s) of livestock, and at the proper stocking rates. Use of the rangeland for domestic livestock production must be optimized with other uses of the resource such as for wildlife habitat, timber production, and recreation. Past mismanagement, especially continual overgrazing by livestock, and reduction of the natural influence of fire has converted many of our rangelands to brushlands. This excessive cover of woody plants, usually of relatively low forage value, often poses a primary deterrent to reaping full benefits from grazing management and, in some cases, even prevents implementation of critical grazing management practices.

Although sound grazing management may retard the establishment of woody plants on rangeland, it has little influence on established woody plants.[1/] Thus, brush management techniques must be employed in conjunction with grazing management to realize potential productivity of rangeland. However, it is critical that sound grazing management be recognized as the most important component of the overall range management system.

The kinds of initial brush management treatments, their application intensity, and subsequent treatment selection depend on the nature of the brush infestation and management goals and constraints. If the goals of management are not defined and achievable (based on range site potential), no brush management system can be expected to perform adequately. Of course, management goals are tempered by constraints such as proximity of susceptible crops, treatment costs, and available capital and labor.

The remainder of this paper is couched in the assumption that management goals are defined, grazing management strategies are sound, and brush management is the primary limitation to optimizing productivity of the range resource. Brush management systems that have been developed or that are being researched for improvement of Texas rangeland will be emphasized. Although specific practices may not be extrapolated

1/ Exceptions are grazing management programs which include goats. Browse is an important diet item for goats and their normal grazing activities may significantly influence established woody plants.

to problems in other areas, the concepts now being research in Texas have broad applicability for improvement of rangeland.

Our research emphasizes "Integrated Brush Management Systems" (IBMS) as a valid approach to vegetation manipulation of natural resources based on "Integrated Pest Management" (IMP) concepts. Application of IPM concepts to natural resource vegetation management has lagged far behind application to cultivated crops because (1) the rate of change in natural vegetation in response to treatment is slower, and (2) most researchers have attacked vegetation manipulation problems on rangelands by developing single practices. However, the single-treatment approach to brush management has not been satisfactory because each practice, whether chemical, mechanical, biological, or prescribed burning, is characterized by certain weaknesses which accompany its unique strengths. The basic premise of IBMS research is to capitalize on the strengths and minimize the influence of the weaknesses of each method by employing them in concert over time to achieve lasting improvement of rangeland vegetation. The slow response rate of natural vegetation dictates that systems can be developed to span 5 to 15 years contrasted to annual systems used with monocultures. Although the rate of research outturn is comparatively slow, the IBMS concept has demonstrated promise for improving ranges in Texas. Some of the most successful systems integrate herbicides, fire, and low-energy mechanical methods.

The objective of IBMS is to expedite the rate of secondary succession on rangeland so that the yield of its products may be optimized on a sustained basis without sacrificing the integrity of the natural resource. This objective must be accomplished within a strict economic framework for acceptance and implementation of the systems by producers.

Advantages of the IBMS concept over traditional single-treatment approaches focus upon improved economics, ecological stability, and managerial flexibility. One of the major advantages is reduced dependence on any particular practice, for example, herbicide use. Also, rangelands supporting species which are not controlled by conventional single-treatment approaches have been improved with IBMS.

One of the prime examples of the effectiveness of IBMS is improvement of rangelands supporting excessive cover of honey mesquite (*Prosopis glandulosa* var. *glandulosa*), the most widespread brush problem in Texas. Honey mesquite can be effectively controlled for 5 to 7 years with the herbicide 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid], on high potential range sites, economic returns are significantly improved when 2,4,5-T is combined with the low-cost mechanical chaining method. The honey mesquite is sprayed, then chained 2 or 3 years after spraying giving an additional 10-12 years of range improvement. Chaining sprayed honey mesquite reduces the energy requirements significantly, when compared, to chaining green brush. This adaption, evolving primarily from producer ingenuity, prompted investigations of the IBMS concept for brush management in the early 1970's.

Management of rangelands supporting Macartney rose (Rosa bracteata), an aggressive introduced plant, is a more recent example of the effectiveness of IBMS. Infestations of Macartney rose may render Coastal Prairie grazing lands essentially useless for cattle production and are not necessary for quality wildlife habitat. The recommended practice, before development of a management system, was multiple applications (often successive annual applications) of 2,4-D [2,4-dichlorophenoxy)acetic acid]. This practice does not always successfully suppress the Macartney rose infestation, is economically unsatisfactory, and has critical ecological limitations such as seriously reducing or eliminating populations of valuable broadleaved plants, especially legumes.

The use of a mechanical-herbicide-fire system or a herbicide-fire system applied in carefully designed patterns to achieve the appropriate mosaic for wildlife has alleviated the restrictions of multiple herbicide applications. Herbicide sprays [2,4,5-T + picloram (4-amino-3,5,6-trichloropicolinic acid)] are applied once at long intervals (presently speculated to be no closer than every 8 to 10 years) with prescribed fire and sound grazing management used in the interim to maintain or improve range condition. The results of this system have been improved botanical composition of the vegetation and increased production of domestic animal products without sacrificing wildlife habitat.

Whitebrush (Aloysia lycioides) is another troublesome woody species which is not effectively controlled by traditional brush control approaches. Conventional mechanical methods and herbicide sprays have been only partially effective for whitebrush control.
However, a new herbicide, tebuthiuron [N-(5-[1,1-dimethylethyl]-1,3,4-thiadiazol-2-yl)-N,N'-dimethylurea] applied in the pelleted formulation at 1 to 1.5 lb/acre effectively controls whitebrush and appears most promising as a part of a herbicide-fire system. Pelleted herbicides improve the ability to place herbicides directly on target, and timing of pellet applications is not as critical as with conventional sprays. After controlling whitebrush with tebuthiuron, fire is used to remove woody debris, increase the standing crop of grasses, and restore the forb population. For example, 1 to 1.5 lb/acre of tebuthiuron increased standing grass to about 3,500 lb/acre in one study compared to less than 1,000 lb/acre without whitebrush control. Where tebuthiuron was applied, however, forbs were eliminated the year of application and production was only 12 lb/acre, contrasted to 50 lb/acre in untreated areas 2 years after treatment. Where fire was utilized as a part of the management system, grass production was increased to 4,550 lb/acre and the forbs were restored. Moreover, the grasses on the treated areas were, proportionally, of higher grazing value than on untreated areas.

the presented examples support the view that only rarely is any single brush management method most efficient for improvement of rangeland. IBMS is one approach based on ecological principles which has demonstrated the potential of attaining realistic management goals within an acceptable economic framework.

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RIGHT-OF-WAY VEGETATION MANAGEMENT: Alternative Control Techniques

William A. Niering

Rights-of-way represent a multi-million acre vegetation resource which should be managed by the soundest ecological methods possible. Over the past several decades this has not been well achieved since much of the management control has lacked ecological expertise. The problem is not one of brush control but of vegetation management. The management objectives should be to remove only that plant cover or vegetation that interferes with the operation being carried out. On transmission rights-of-way, tall-growing trees must be removed; low-growing plant cover should be preserved. Along roadsides only that vegetation which interferes with sight-line conditions needs to be removed to achieve these objectives. Several techniques can be employed. With the advent of herbicides and their promotion by the industry, herbicides gradually replaced most mechanical techniques. Currently, with the potential hazards associated with 2,4,5-T there is a growing search for alternative techniques. The concern about 2,4,5-T has arisen out of the indiscriminate use of this material primarily as aerial or foliar sprays. Therefore, if materials such as Tordon are used, they should be used only in a very selective way in order to prevent any possible health hazard.

The Northeast Forest Experiment Station has actually pioneered in the sound use of herbicides on roadside rights-of-ways within National Forests (McQuilkin and Strickenberg 1961). The Eastern Region of the Forest Service (R-9) has also recognized the special management requirements for the more than 35,000 acres of rights-of-way that occur within their Region (USDA-Forest Service 1966). For a more extensive review of sound right-of-way management and an evaluation of issues and alternatives see USDA Forest Service Symposium, February 1978, The Use of Herbicides in Forestry (Niering 1978).

Management Alternatives

Herbicides: Herbicides still offer the most viable alternative and are currently the primary tool used by most right-of-way managers. The techniques used, however, vary considerably. There is still too much use of broadcast foliar sprays which have the following limitations:

1) Lack of selectivity
2) Loss of desirable ground cover
3) Inadequate root kill of undesirable species
4) Drift of chemical and damage to desirable growth including home gardens, agricultural crops and watersheds.
5) Opening of site conditions for the potential invasion of undesirable tree growth.

Sound alternative techniques including stump and basal treatments have been employed on the Connecticut Arboretum Right-of-Way Demonstration Area (Niering and Goodwin 1974) and have been implemented in commercial practice on Northeast Utilities rights-of-way in Connecticut. They should serve as a model in the development of a selective policy for the Forest Service. Northeast Utilities specifications dated March 31, 1975 state... "the objective of woody vegetation control is to selectively control that woody vegetation which is or will be interfering with the line which occupies the right-of-way. However, all herbs, most shrubs, and some low mature height trees are normally considered desirable, and they shall be preserved and encouraged to grow." These specifications are carried out commercially by using selective stump or basal sprays on a competitive bid basis. The average cost for stump treatment in the southern New England area is $347.00 per acre using Tordon 155, one of the most effective chemicals, especially on root suckering species. For selective basal sprays most widely employed, the cost ranges from $74.00 to $221.00 per acre, averaging around $130.00 per acre. A 6-8 year spray cycle has been formulated. Foliar applications can run $255.00 per acre using Ammate. Broadcast sprays of 2,4,5-T are not recommended. Stem foliar sprays should only be used where other more selective techniques cannot be employed. If chemicals are used, only selective techniques should be permitted as outlined here. The advantages with the selective approach are:

1) Preservation of desirable plant cover and development of relatively stable mosaic of vegetation types that deter future tree invasion
2) Excellent root kill of undesirable species
3) Creation of excellent wildlife cover
4) High esthetic values

Cutting or Girdling: These are viable techniques if manpower or mechanical cutters are available. The latter are being employed extensively in lieu of herbicides on certain railroad rights-of-way, i.e., central Vermont, where indiscriminate foliar sprays are much overused. Mowing usually only temporarily arrests woody development since many species resurge or root sucker following cutting. Therefore, periodic recutting is required. Girdling or the stripping off of a cylindrical section of bark is also an excellent technique for killing unwanted trees. If manpower is available, selectively girdling or cutting undesirable tree growth is an environmentally sound alternative, especially along the right-of-way where chemicals might be hazardous to employ.

Burning: This technique has been found applicable on relatively level terrain in the South (Arner 1976). It represents a technique which will probably increase in importance in the future since it has high energy conservation value. In Australia, burning is used extensively on right-of-way vegetation especially along railroads through pasture land. Although smoke pollution may be a potential hazard, it is a natural technique which should be employed wherever possible.

Recommendations

The following recommendations are made to help formulate a national right-of-way management policy on transmission, gas, railroad, and roadside rights-of-way crossing National Forest lands:

1) A selective right-of-way management policy should be instituted which employs a mix of the various techniques discussed.
2) Broadcast aerial and ground sprays should not be permitted on rights-of-way within National Forest land unless other more selective techniques such as basal and stump treatments cannot be employed.
3) In terms of a chemical approach the Northeast Utilities specifications are recommended as a model. Although the selective approach appears more costly initially when calculated on a long range basis, it is a more economic and sounder ecological management regime.
4) The Engineering Division of the Forest Service, where right-of-way recommendations are now controlled, should be assigned ecological expertise. And a sound set of specifications should be formulated maintaining roadsides and private utilities rights-of-way on National Forest lands.

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VEGETATION MANAGEMENT: AN INTEGRAL PART OF FORESTRY

Mason C. Carter

Last February, Wes Rickard, Harvey Holt and I presented a paper on Alternative Methods of Vegetation Management for Timber Production at the Symposium on the Use of Herbicides in Forestry sponsored by USDA and EPA. Although several members of the audience here today attended the February meeting and heard the earlier paper, I cannot avoid certain repetition because of the similarity of the subject matter. But I will omit the cost-benefit analysis contained in the February paper and expand the discussion of alternatives and the integration of vegetation control in overall management.

Minor Practices

Various weed control or vegetation management practices are necessary in nursery and seed orchard management. Some of these operations are quite complex and worthy of careful study and planning. But the total acreage involved nationally is no more than a few thousand acres, and we do not have the time to explore these subjects in detail.

Likewise, the control of herbaceous competition in recently established plantations is vital in some situations, but the level of such operations is minor compared to other practices.

Site Preparation and Stand Establishment

The major vegetation management or weed control operations practiced today are directed toward regenerating, naturally or artificially, even-aged stands of conifers following a harvesting operation.

Since most conifers are pioneering species which require full sunlight and considerable freedom from competition, unmerchantable species left standing after a harvest must be removed or suppressed. If the suppression or removal methods do not adequately prevent sprouting, a further operation to release the young conifers may be necessary.

Site preparation can be accomplished by:

1) chemical treatment;
2) mechanical equipment;
3) fire;
4) improved utilization;
5) a combination of methods.

<u>Chemical Treatments</u>: Herbicidal sprays, especially when followed with a thorough burn, can be effective in deadening residual woody vegetation and removing debris, thus creating a good seedbed or planting site for conifers.

Such treatments are relatively low in cost, can be applied in steep or broken terrain, and produce no significant soil disturbance beyond, of course, that produced in harvesting.

The principal disadvantage of this treatment is the chemicals themselves and the uncertainty and controversy surrounding their use.

The most widely used herbicide for this purpose is 2,4,5-T, and I do not think I need mention the controversial nature of this material. Substitute materials such as picloram (Tordon) or glyphosate (Roundup) are considerably more expensive than 2,4,5-T and not always as effective.

Picloram leaches readily from the surface soil, but is quite resistant to biological degradation. It is also quite toxic to conifers and may be absorbed through the roots, causing mortality in adjacent unharvested areas.

Spray and burn treatments rarely result in adequate suppression of sprout growth. Thus, one or more additional spray treatments are frequently needed to release the young conifers.

For release sprays, there are no substitutes for 2,4,5-T since the alternative chemicals are toxic to most conifers.

Mechanical Equipment: Where terrain permits, heavy machinery has been widely used for site preparation, especially in the southern pine region. Bulldozing, shearing, crushing, chopping--with or without burning--can be effective. Sites which are cleared may be disked or bedded to further improve seedbed conditions and retard regrowth.

Recent advances in utilization, especially whole-tree chipping, may ultimately eliminate the need for a felling or clearing operation. Harvested sites may be disked, bedded or planted immediately, without additional preparation. The marketability of whole-tree chips varies greatly, but the prospects for increased utilization are high.

Disadvantages of mechanical site preparation methods are: 1) cost, 2) soil disturbance and water quality impacts and, 3) terrain limitations. In some instances, the more effective mechanical methods reduce plant diversity.

The Use of Fire: Fire is an extremely useful tool, especially in the southern pine region. But fire is a sanitation or prevention method, not a single application tool, unless of course, it is applied in the holocaustic fashion of natural wildfires.

If fire is used frequently throughout a pine rotation, the need for site preparation after harvest may be all but eliminated.

Frequent, extensive burning may create serious smoke management problems and lead to undesirable air pollution.

Fire is a delicate tool, requiring a narrow range of fuel moisture and atmospheric conditions. Proper conditions may occur infrequently or not at all in some regions. Burning is most successful in level or gently rolling terrain. In steep terrain, burning is inconsistent and extremely difficult to control.

Manual Methods: Concern over the impact of chemical treatments has led to suggestions that hand cutting methods be employed for conifer release operations. It is inconceivable to me that such practices would ever be employed on a large scale.

The cost would be enormous, not to mention the social and environmental problems involved in securing and maintaining such a huge labor force.

If massive public works programs are developed, I would hope that more suitable projects take precedence, such as rebuilding this Nation's railway system.

Intermediate Treatments

Uneven-aged management, widely advocated for many hardwood forest types, requires careful control of species and tree quality. Deadening low value or cull trees for timber stand improvement is a widely used and important practice.

Manual or mechanical methods can be used for timber stand improvement, but they are more expensive and less effective than methods involving chemicals.

In recent years, hardwood utilization standards have changed dramatically. Most of the trees formerly considered to be worthless can now be sold. The major limitation is having adequate volume to support a harvesting operation.

With continued improvement in the market, improvement cuts may well replace most of the need for timber stand improvement operations.

Integration of Vegetation Management

By its very nature, vegetation management--including what could be called forest weed control--has always been an integral part of forestry. If a forester doesn't manipulate the vegetation, he doesn't practice much forestry. After all, the basic tool of silviculture is the axe.

In fact, when we single out forest weed control as a separate practice for a study of integrated pest management, we run the risk of defeating our purposes. A weed is only a weed if it has no net value.

Utilization should be the first goal; sanitation should be next. When we cannot prevent the establishment of less desirable vegetation, and we cannot sell or otherwise utilize it, only than should we resort to control methods.

Because forest management is a long-range operation, and vegetation management such an integrated operation, changes in any operation can seldom be accomplished simply and rapidly.

For example, let's assume I am woodlands manager for a forest products operation in the southern pine region. I have 1/2 million acres of loblolly pine land managed on a 35-year even-age rotation system supplying a pulp mill, a sawmill, and a plywood plant. Our manufacturing operation consumes only pine at the sawmill and plywood plant, but you can use up to 20 percent hardwood at the pulpmill.

For regeneration after harvest cutting, I use 2,4,5-T spray, followed with burning and hand planting of pine. When plantations are 2 years old, and again at 5 years, I spray with 2,4,5-T for release.

But local environmental groups are strongly opposed to the use of 2,4,5-T. The New York office is also urging me to find other methods, so long as they don't result in higher costs or lower pine production.

Discussion with the pulp mill manager leads to a plan for utilizing whole tree chips in the boilers. Cost to modify the boilers is 1/2 million dollars. For about a million dollars I can develop two in-the-woods-chipping operations. Now I can utilize all of the previously unmerchantable material during the harvesting operation. No more spray and burn will be necessary. Harvested areas can be disked or bedded to reduce sprout growth and machine planted. Another half million dollars worth of site prep and planting equipment will be needed. But over the next ten years, the savings on fuel at the pupl mill, plus the improvement in pine production, will offset the capital investments. If I step up my burning program during rotation, site preparation cost may be further reduced. With careful planning the same crews can be used for burning, site prep, and planting.

I report my plans to the Vice President in New York and he says "Great! Go to it. I can't wait to tell the President and Board that no more 2,4,5-T will be used, and you will actually need less operational money."

Now I have to give him the bad news. I need two million in capital now and I cannot stop using 2,4,5-T for at least 5 years. I have around 60,000 acres of plantations less than 5 years old which need to be released.

Getting the whole-tree chippers operational will take at least one year--maybe two; chippers have a 6 to 9 month delivery schedule and operators require training. Burning must begin on a regular basis at least 5 years before harvest if site preparation costs are going to be reduced. Thus, we will have to spend more money and continue to use 2,4,5-T for awhile at least, but long range prospects look good.

The State Department of Natural Resources will be happy to see us step-up our burning program--should improve wildlife habitat. But they don't like the whole-tree-chipper or mechanical site prep. It eliminates too much food and cover, especially the oaks that recovered from 2,4,5-T, and they are concerned about the erosion it may cause in the rolling country on the northern part of our lands.

The local environmental group will be delighted to see a reduction in aerial spraying, but they raise cain about our burning in that 70,000 acres west of town. They won't like it when I tell them we will be burning 10 to 12,000 acres within two miles of the city limits. The same goes for the highway department, especially down south where Interstate 65 runs through the middle of our land.

After a prolonged silence, the Vice President observes, "Sounds like you are replacing one set of risks with another."

"That's right," I reply, "but hopefully, the net result will be positive."

"When is EPA supposed to give us a final decision on 2,4,5-T?," the Vice President asks.

"Next April, I think," is my answer.

"Well, send me a full written report and I will give it some thought between now and April."

And so it goes. Forest management, like most of man's modern-day enterprises, is a very complex network of interdependent processes. The scenario I have recited is really over-simplified. The action-reactions I have cited will certainly vary with terrain and local conditions.

The example serves to indicate how forest weed control is fully integrated in a well organized forest management system and how changing one facet necessitates modifications in others.

It is impossible to practice forest management without taking risks. The challenge is to define the level of acceptable risk and to avoid increasing one risk while reducing another.

THE USE OF MICROBIAL AGENTS AND UNCONVENTIONAL CHEMICALS IN FOREST PEST MANAGEMENT

David L. Wood[1/]

Introduction

The use of chemicals and microbial agents in forest pest management for survey, prophylaxis, and direct suppression of populations should be visualized in a systems context (fig. 1). A treatment aimed at reducing the pest population density may cause changes in forest stand parameters such as mortality rate, growth rate, density, and age and species distributions. Such changes must produce sufficient protection of existing values

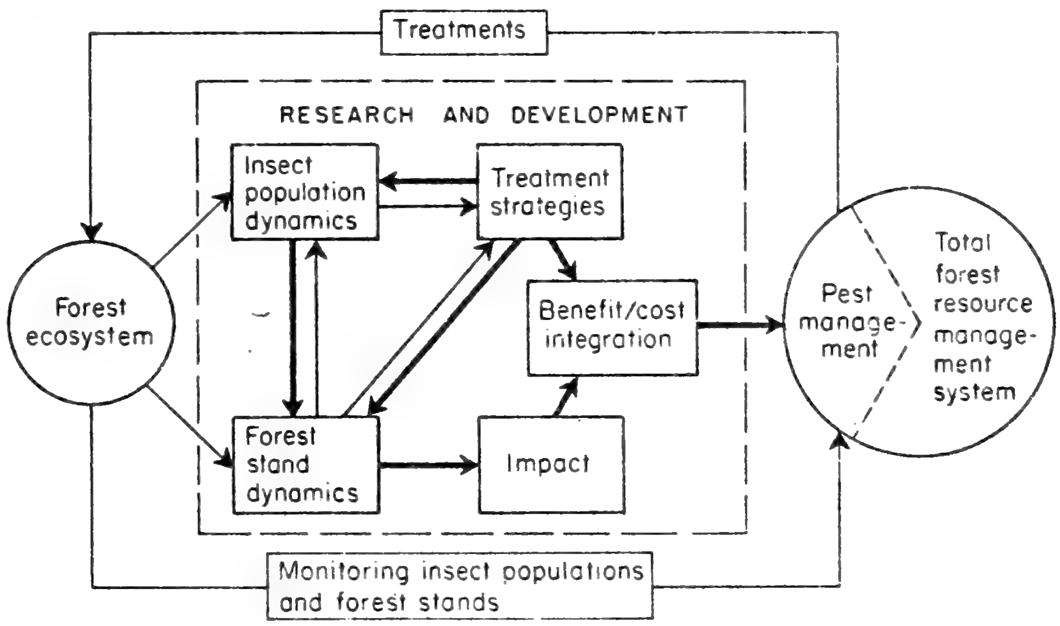

FIGURE 1. Model structure of an insect pest-management system, with research and development components and the action sequence

or a gain in values (i.e. efficacy) to justify the cost of treatment. Also, treatments must meet all environmental safety requirements. After a particular change in forest stand parameters has been demonstrated for a treatment tactic, a preliminary analysis of the potential benefits

1/ Most of this paper was excerpted from Wood, D.L. 1977 (Manipulation of Forest Insect Pests, in "Chemical Control of Insect Behavior: Theory and Application," H.H. Shorey and J.J. McKelvey, Jr., eds., Wiley Interscience, New York, pp. 369-384) and Wood, D.L. 1978 (Development of Behavior Modifying Chemicals for Use in Forest Pest Management in the USA, Advanced Research Institute on Chemical Ecology and Odour Communication in Animals, Hague, Netherlands, September 25-29, 1978) and from interviews with Dr. C.G. Thompson (Forestry Sciences Laboratory, USDA Forest Service, Corvallis, Oregon), Dr. F.W. Cobb, Jr. (Dept. of Plant Pathology, Univ. of Calif., Berkeley), and Drs. W.E. Waters, J.E. Casida, and P.A. Rauch (Dept. of Entomological Sciences, Univ. of California, Berkeley).

(i.e. impact assessment) and treatment costs should be made prior to undertaking the research necessary to demonstrate the efficacy and safety of a treatment.

Because forest crops have a very long rotation period compared to most agricultural crops, it is much more difficult to determine the benefits of a proposed treatment tactic, even when it has dramatic short-term biological effectiveness. Benefits and costs must be distributed over the length of the rotation, which may vary between 20 and 100 years for sawtimber. Monetary values may change considerably during this period. This describes the basic dilemma for forest pest management regardless of the pest (insect or pathogen) suppression treatment proposed, [i.e. insecticides, microbial agents, insect growth regulators (IGRs), behavior modifying chemicals (BMC's), fungicides, etc.] Also, efficacy and safety data must be obtained for any proposed treatment tactic that utilizes a chemical or microbial agent so that registration can be sought from regulatory agencies. Thus, we must determine effects of the treatment on such parameters of the pest population dynamics as density, trend in density, degree of aggregation, and effects of natural enemies. In the interest of safety, data on effects of the treatment on man and other nontarget organisms are essential. Such information is available for very few treatment tactics that utilize chemicals or microbial agents.

Efficacy Tests

Proof of efficacy should include information on the density of the pest and, in most instances, the incidence and severity of crop damage before and after the test. Efficacy tests should be required in different geographical areas where differences, known or potential, may occur in the species' response to the defined chemical or microbial agent. In those cases where a specific hazard is shown to exist in areas adjacent to the treatment (often called "downstream effects"), data estimating the hazard should be presented. 2/

The scientist must prove that a statistically significant reduction in the pest population can be achieved consistently by a particular treatment. However, such demonstrations are only the first step. A treatment must be

2/ The above is excerpted with minor changes in wording from a report prepared for the EPA by a committee comprised of T.W. Brooks, Conrel Corp.; W.E. Burkholder, USDA and University of Wisconsin; R.T. Cardé, Michigan State University; D.L. Chambers, ARS-USDA, Gainesville, Florida; W.L. Roelofs, Cornell University; H.H. Shorey, University of California, Riverside; and D.L. Wood, University of California, Berkeley (chaired by W.L. Roelofs); entitled "Analysis of Specialized Pesticide Problems, Invertebrate control Agents--Efficacy Test Methods, Vol. 10, Behavior-modifying Chemicals: Attractants and Mating Stimulants."

further tested at the crop protection level. nus, field tests must be designed that demonstrate:

1. the relationship between the number of a particular lifestage of the pest and the tree damage caused by the pest; and

2. the relationship between changes in the numbers of this lifestage caused by a treatment, and subsequent tree damage.

The relationship between populations and damage levels is known for only a few pest species in North America, e.g. eastern spruce budworm, gypsy moth, lodgepole needle miner, Douglas-fir tussock moth and mistletoes. Notably absent from this list are destructive species of bark beetles and most tree pathogens.

The investigator soon discovers that the population approach is quite different from that of assessing individual insect behavior or mortality in the laboratory and in field experiments, where compounds or agents applied in various mixtures and at various rates are evaluated for their effects over small areas and over short time periods (<1 hectare and 1 to several days). In order to establish a cause and effect relationship between treatment and damage levels, the very difficult questions in insect population biology that relate to the estimation of pest population levels and damage through time and space must be answered. Forest pests can cause damage over very large areas, often greater than 2,000,000 ha. Therefore, chemicals or microbial agents must be evaluated for efficacy over representative portions of these infestations. In some applications, such as mass-trapping using behavior modifying chemicals, total populations are estimated in order to relate the catch to the degree of population reduction and to subsequent damage levels. The size of treatment and check plots is very difficult to determine because the mobility of the species under study will affect how the concept of "plot" is used.

If obtaining the above efficacy and safety data were not already too complex, in order "...to manage such pests effectively, it is vital that we have the capability to anticipate and forecast their occurrence, abundance, population trends and potential damage..." so that "...we are able to specify in advance the expected outcomes of different control treatments and strategies." 3/

"Measurement of pest populations and the biological damage inflicted on the host(s) by those populations, placing these in a value framework,

3/ Waters, W.E. and B. Ewing, 1976. in Modeling for Pest Management, Concepts, Techniques, and Applications; R.L. Tummula, D.L. Haynes and B.A. Croft, eds., Michigan State University, East Lansing, Michigan. pp. 19-31.

and developing the ability to forecast changes in populations, damage, and values, are essential to the efficient practice of forest pest management." [4/]

Thus, only after our efficacy studies have demonstrated what damage and how much can be prevented (i.e. mortality, growth increment, deformation, etc.) can the managers place a value on the potential gain. This value, together with the cost of the treatment, must then be projected over the length of the forest rotation with and without the treatment in order to determine the economic feasibility of the treatment. Of course, the necessity for future treatments will also depend upon whether or not treatments are made today. Such economic analyses are rare for any treatment aimed at reducing the pest population directly. Recently, economists at the University of California, Berkeley, have undertaken such a study to determine how to estimate what values might be saved through the application of a behavior modifying chemical to reduce western pine beetle-caused mortality of ponderosa pine. By hypothetically changing the probabilities of tree death by the treatment, the volume of lumber saved can be predicted and its value estimated so that a maximum treatment cost can be derived from treatment-induced changes in the probabilities of tree death caused by the beetle. Other resource values such as recreation and watershed will be evaluated later.

Status of Microbial Agents and Unconventional Chemicals

Behavior-Modifying Chemicals (BMC): The BMC's included here are attractants, repellents, arrestants, feeding and oviposition deterrents, and feeding, oviposition, and locomotion stimulants. They are promising alternatives and supplements to the use of insecticides for the management of forest pests. The first BMC's from a forest pest were identified in 1966 from a western bark beetle species, *Ips paraconfusus*.[5/] Since that time, extraordinary progress has been made in the identification of BMC's for many of the most destructive forest insect pests in North America. Further, most of these compounds have been tested under field conditions in a great variety of small-scale experiments aimed primarily at assessing the activity of the synthetic compounds in various mixtures and formulations. However, large-scale (>250 ha) suppression or prophylaxis, (e.g. individual tree protection) efficacy tests have been conducted for only a very few forest pest species. There have been no published accounts of the human and environmental hazard that might accompany the use of BMC's for any species. Thus, the critical information on efficacy and human and

4/ Anderson, L.S., A.A. Berryman, D.G. Burnell, W.H. Klein, E.L. Michalson, A.R. Stage and R.W. Stark 1976. *in* Modeling for Pest Management, Concepts, Techniques, and Applications, R.L. Tummula, D.L. Haynes and B.A. Croft, eds., Michigan State University, East Lansing, Michigan. pp.149-164.

5/ Silverstein, R.M., J.O. Rodin and D.L. Wood. 1966. Science, 154, 509-510.

environmental hazard of a BMC treatment needed to seek registration by regulatory agencies is not available for any forest pest species. Nor is the highly integrated information required for benefit/cost analyses of potential BMC treatments available to the land manager who must make the decision to treat or not.

The population dynamics of several forest pests have been the subject of intensive and extensive study and these studies have contributed significantly to our understanding of insect population dynamics. However, no one has directly related the number of adults to damage levels, but all BMC's identified to date affect adult behavior. Thus, the need to provide efficacy data for BMC's must bring together expertise from population and behavioral biology as well as forest ecology.

A. Pest suppression

Although behavioral effects of BMC's in small-scale field tests have been determined for 17 forest insect species in North America, there are only four cases where crop protection effects through pest suppression have been measured (i.e. an ambrosia beetle, smaller European elm bark beetle, southern pine beetle, and western pine beetle). Except for the ambrosia beetle, either no protection was demonstrated or the results are open to multiple interpretations. For example, the relationship between the catch of bark beetles on sticky traps baited with attractants could not be related directly to the population of beetles that killed trees before and after the experiments. Therefore, a decreasing trend in tree mortality could be due to mortality agents other than attractants in sticky traps. These pioneering studies indicate the difficulty in demonstrating the required cause and effect relationship between the trend in tree mortality and treatment-induced beetle mortality. No crop protection effects have been demonstrated for any forest defoliators using BMC's to interrupt mating.

B. Prophylaxis

Experiments have been conducted to demonstrate tree protection by interruption of bark beetle aggregation with BMC's:

1. Living trees are treated with BMC's to lower the attack rate and/or prolong the period of attack and thus decrease the chances that the beetles can overcome natural host resistance mechanisms, e.g. rate of flow and amount of oleoresin. Thus, the beetles are killed during the concentration phase of host colonization by the tree, by increased exposure to predation, and/or by fatigue.

2. Logging debris or wind-felled trees are treated with BMC's to interrupt aggregation. This results in lowered attack densities and a subsequent reduction in the size of the next generation. Many species of bark beetles breed in such host material and then attack and kill nearby living trees.

Lowered tree mortality has not been demonstrated in either situation.

C. Survey

BMC's have been used successfully for the detection of new infestations of the gypsy moth for several years. Traps baited with attractants are being used to detect the European pine shoot moth. These new detection methods are extremely valuable to land managers who face the continued threat of the introduction of these serious exotic pests into new areas. For example, a recent infestation of the gypsy moth was detected in San Jose, California, and apparently successfully eradicated in 1976. The success of this operation was attributed to the early detection of male moths in BMC-baited survey traps.

BMC-baited survey traps are being tested over several western states to assess their effectiveness in detecting increases in Douglas-fir tussock moth populations. Recently, western spruce budworm has been detected in survey traps from many areas of northern California where heretofore only occasional records were known. The effectiveness of several BMC-baited commercial traps for monitoring eastern spruce budworm populations has been determined. To my knowledge, no BMC's are being used to detect bark beetle populations for timing of suppression efforts. Also, no relationship has been reported between the catch on BMC-baited traps and estimates of the size and location of forest pest populations. As with the evaluation of suppression efforts, this research falls in the difficult area of population measurement and prediction.

Insect-Growth Regulators (IGR): The IGR's included here are antimetabolites and insect hormones and their derivatives. Many of these compounds have been screened for activity against forest pest species, but to my knowledge only one, Dimilin, has been registered. Some are quite specific and degrade very rapidly--for example, methoprene, a juvenile hormone analogue. However, some are active across a broad spectrum of organisms. Certainly a chitin synthesis inhibitor like Dimilin has the potential of being a broad spectrum compound, when one realizes that chitin is not only the principal structural material in the insect cuticle, but also functions similarly in other invertebrates as well as in the cell wall of fungi. However, this compound and its relatives are known to act somewhat selectively in arthropod chitin synthesis and are apparently inactive in the fungi.

Microbial Agents: The successful field testing and subsequent registration of the Douglas-fir tussock moth and gypsy moth viruses must be considered an outstanding accomplishment in the research and development of methods of forest pest control to supplant conventional insecticides. Safety studies were conducted on the commercial formulations and included inhalation and dermal inoculation studies. No abnormalities were detected. Field tests conducted in northeastern Oregon in 1973, in British Columbia in 1975, and in New Mexico in 1978 all demonstrated a reduction in tussock moth populations and tree defoliation. Enough virus has now been commercially produced to treat 20,000 hectares, but this is far too little for practical application. The treatment is aimed at the first year of an outbreak in an attempt to infect 30 percent of the population. The ensuing

epizootic is expected to lower populations before top kill and tree mortality occur. As this strategy depends upon a reliable detection system, the tussock moth sex attractant (pheromone) will undoubtedly play a significant role in this pest management system.

A nucleo-polyhedrosis virus can be used effectively against the spruce budworm but the yields of polyhedra are very low and thus apparently not economically feasible at this time. The same problem exists for the hemlock looper. Tissue culture methods are not promising at this time, also because of high cost. Work is underway on a granulosis virus in spruce budworm. The only known epizootic of a granulosis virus in North America was observed on the western and "green-form" spruce budworms. Research is advanced on the European pine sawfly virus.

The bacterium, Bacillus thuringiensis (BT), has proven to be too erratic in lowering populations of several defoilating species and thus the conditions of reliability still need to be determined. Also, BT is considered by some to be economically marginal. Other compounds, such as chitinase, have added to BT formulations to enhance activity, but these studies are controversial. Also, adding other compounds to BT formulations greatly complicates the registration process. Perhaps the short residual life of BT accounts, in part, for its erratic behavior. Work is underway to isolate more effective strains and to define in more detail the nature of their toxic principles. With both viruses and bacteria, aerial application technology needs to be improved, and more persistent formulations need to be developed.

Tree Pathogens

The amelioration of damage by forest pathogens continues to be largely a result of stand manipulation. This is best exemplified by the mistletoes where the infected overstory must often be removed to prevent infection of the understory trees. Whole-tree logging (including the large roots) has promise for lowering the incidence of Fomes annosus and perhaps other root pathogens in managed stands. Crop rotation and resistant varieties continue to be promising methods of disease management. Breeding for several genetic traits instead of resistant traits controlled by a single gene should be encouraged. Races of various pathogens must also be considered in breeding programs.

Chemicals have very limited use in forest-wide applications against tree pathogens when compared to nursery and Christmas tree applications. Borax is a very effective treatment for prevention of stump infection by Fomes annosus, but is not widely incorporated into current forest management practices. No chemical methods are known, or apparently practical, for treating the several other very important root pathogens found in the coniferous forests of North America, e.g. Verticicladiella (Ceratocystis) wagenerii, Armillaria mellea. Chemicals have the greatest promise against foliar diseases. Most notable here is the effectiveness of copper oxide for the control of the red-banded needle blight (Dothistroma pini) on Monterey pine in New Zealand. Here one treatment effectively lowers disease severity for at least two years. Meanwhile, tree resistance is increasing with age. Thus, perhaps only 2-3 treatments would protect the

trees until they were able to outgrow the fungus at 10-15 years of age. Similarly, Bordeaux mixture is effective against brown spot needle blight of longleaf pine. I am not familiar with the research currently underway on chemical control of forest pathogens.

Problems

1. Research and development on chemicals for use in forest pest management continue to be characterized by insufficient coordination through the planned successive phases from discovery of biological activity, to laboratory testing, to small-scale field experiments, and to larger-scale pilot tests. Usually the research is aborted somewhere prior to efficacy determination, with inconclusive results for applications.

2. Integrated pest management research and application programs have shown the advantages of a coordinated approach and commitment of people and resources to agreed-upon products and goals. This does not mean all research on chemical controls must be committed to such a tightly coordinated effort. However, even research projects and pilot tests of single control tactics should be evaluated for their usefulness in an integrated pest management systems context.

3. With the exception of only a few compounds (i.e. Dylox, Orthene, Carbaryl and Dimilin), private industry's commitment to the research and development of chemicals for forest pest management undoubtedly derives from potential markets in agriculture. Thus, we cannot look forward to a continued input from industry for the development of efficacy and environmental safety data for most forest pests because the costs are not justified by the potential benefits. Also, compounds with activity against a broad spectrum of pest species would appear to be most desirable from a profitability standpoint. An expanded effort to obtain industry's cooperation needs to be made by agencies concerned and responsible for developing new materials. However, with highly selective and specialized agents and compounds like viruses, bacteria, fungi, hormones, and behavior modifying chemicals, the USDA Forest Service and other public agencies may have to shoulder the full burden of testing from discovery of activity to registration. This may include responsibility for production and synthesis of such agents and compounds. This means that the agencies will have the opportunity to control field evaluations and subsequent use which are especially needed for biologically efficient methods in pest management systems. Also, we cannot expect the needs for forest pest management to be met by conventional compounds alone, especially those developed for agriculture.

Conclusion

The evaluation of the present status of chemicals and microbial agents in forest pest control in the USDA Forest Service, and the development of guidelines for future directions and priorities in this aspect of resource management, must be done in the context of their contribution to integrated pest management as described above. Such an evaluation of pest

management tactics and strategies must be over the planning horizon of forest resource managers. These are the criteria for evaluation of present and future research and development efforts, not only for chemical and microbial controls but for other research activities concerned with insects and diseases, e.g. surveys and sampling methods.

FOREST MANAGEMENT AND INTEGRATED PEST MANAGEMENT

R. W. Stark

Introduction

I have been honored by being asked to explain here what integrated pest management is, why it is needed, and how it might be implemented.

Defining integrated pest management is somewhat like the six blind men of Industan describing an elephant--it all depends on where you are coming from. This spring we held a symposium to do the above for one insect--the mountain pine beetle. That took two and a half days and 20-odd speakers. This summer a Forest Service Workshop was held to describe the Douglas-fir tussock moth management system. That took about 10 people and two days.

In spite of the size and complexity of the task, with appropriate lack of humility, I will take a crack at it--taking comfort in the fact that this is a colloquium and most, if not all, of the members assembled here have much more than a nodding acquaintance with the subject. You will, I am sure, fill in the inevitable gaps, correct any uncertain logic, and temper my optimism.

What it is

Integrated pest management is a component of forest protection which is a part of forest management. Forest management objectives--optimization of resources--are our objectives. Forest protection against pests has two major functions:

1) to provide appropriate information on forest pests to assist forest resource managers in their decisionmaking;

2) to provide environmentally acceptable alternative strategies and tactics to reduce numbers of forest pests when that is the decision.

The latter function is what is commonly considered as integrated pest management. These functions are inseparable in the context of forest protection. Perhaps we should coin a new term embodying the total concept--Integrated Forest Protection Against Pests (IFPAP). This is not meant to be facetious--the term integrated pest management has been extensively defined in the world literature, largely agricultural, and does not encompass all that is implied in carrying out forest protection functions.

The principal long-range goal of IFPAP is to assist the resource manager in developing resource production systems which are less vulnerable to pests than present ones.

The short-term goal with which we have been largely preoccupied to date, is of ameliorating (controlling) existing pest problems.

Progress towards the long-term goal is made through appropriate management of the two sides of the equation--the resource managed for and potential pest populations. For this goal to be reached requires complete, immediate interaction of both management groups.

The decision support system

To describe this function of IFPAP one must begin with resource management planning--like Siamese twins they are inseparable. Resource management plans are typically based on long-range forecasts that consider normal losses but rarely abnormal pest situations such as insect outbreaks or disease epidemics (Anderson and others 1976). To include such occurrences the resource projections must be merged with pest population models and other resource limiting factors.

The planning process to realize this integration is continuous but consists of four major activities (Anderson and other 1976):

1. Definition of resource management goals, constraints, and values. Goals and values will vary widely from forest to forest and will include several alternatives and values. Presumably, for National Forests at least, these definitions will evolve from the RPA/NFMA process. Constraints may be legal, political, social or economic (Waters 1973).

2. Description of the current status of the forest stand in sufficient detail to support prognoses of the effects of potential management regimes on resources. The timber management planning inventory (Stage and Alley 1972) is an example of this for one resource.

3. Development of prognoses of the consequences of alternative management regimes. These include the value criteria relative to the resource(s), goals, and constraints of management. For example, stand prognosis procedures have been developed which provide a sequence of timber yields by time interval for each stand class under each management alternative (Myers 1968; Stage 1973). Similar procedures undoubtedly could be developed for other resources such as recreation or wildlife. These data provide input for the fourth phase--the selection of an optimum mix of management activities.

4. Comparison of alternatives against criteria established in (1) and selection of the optimum mix of management activities that comes closest to meeting the objectives. Computational techniques for this process are available for the timber resource (Navon 1971) and perhaps other resources.

It is important to realize that this entire planning process must take place before integrated forest protection against pests and integrated pest management can be fully operational and useful.

Describing stand development under alternative management prescriptions for pests, wildfire, diseases, etc., has been compared to a railroad switching yard in which vandals may missect some of the switches (Stage 1975). The resource planner can set his switches to avoid major hazards only if these are made visible and their consequences with respect to management goals, constraints, and values described.

For illustrative purposes only, I have used what we have called the Douglas-fir tussock moth management system (fig. 1). To this point I have dealt only with the "stand prognosis model" and the steps leading to its development. The second portion of what I have termed IFPAP is exemplified by the tussock moth outbreak and pest management model structure (Overton and Colbert, In Press); comparable models are available for the mountain pine beetle, the gypsy moth, dwarf mistletoe and possibly others. By using pest, rather than tussock moth, I am trying to emphasize that this structure or something like it can be developed for any pest/host system.

Very briefly, the outbreak model simulates outbreaks of the tussock moth and describes what will happen in the stand under various management alternatives in the presence of an outbreak. Development of such a model requires thorough knowledge of the biology and ecology of the pest, some level of predictability of population fluctuations, some measure of probability of attack on trees and stands, and understanding of the biological damage inflicted on the host species which is capable of being translated to the stand level (Stark 1977; Campbell and McFadden, In Press).

The biological impact or damage to the trees and stands is converted into value impacts for any particular resource by socio-economic models--the socio-economic translator in fig. 1. Thus the resource manager now has the information in hand concerning impact of an uncontrolled outbreak in the context of his goals and objectives.

The model also incorporates various treatment strategies, makes assumptions of degree of control based on historical data and simulates treatment. Given information on treatment costs, and the outbreak model output, converted to stand impact, the socio-economic translator can derive costs and benefits of various alternatives. The "switching yard" concept (Stage 1978) with the more elegant name "decision-tree analysis" has been used to describe how this information may be used in the selection of control alternatives (Talerico and others 1978).

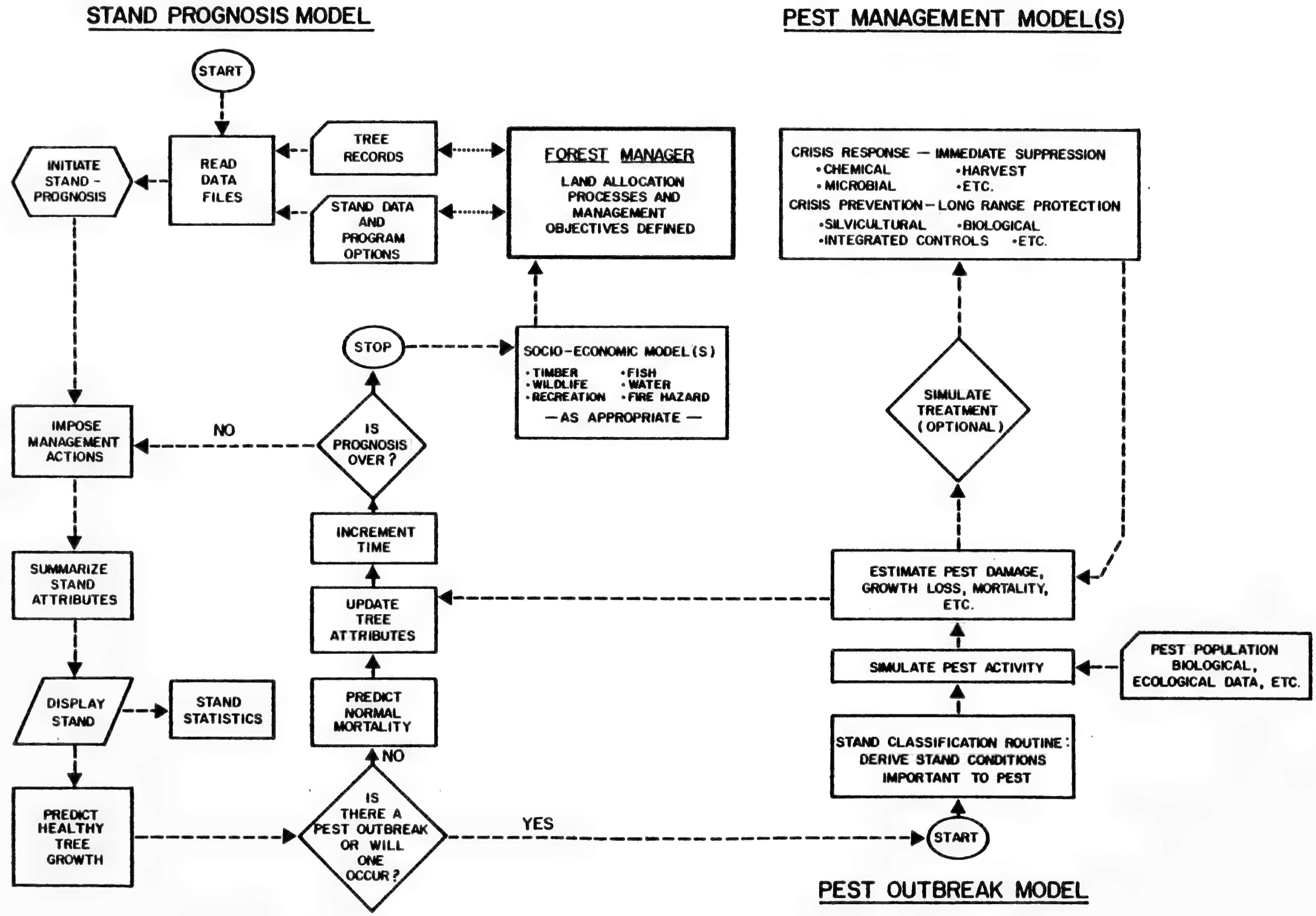

FIGURE I. LOGIC OF A COMBINED STAND PROGNOSIS-PEST MANAGEMENT SYSTEM MODEL

The treatment function

The pest management model or treatment portion of the tussock moth management model consists of single tactics or a combination of tactics designed to reduce pest populations to tolerable levels without undue insult to the environment. These tactics or strategies may be short-range--responding to an existing pest problem (crisis response) or long-range--reducing the probability of future problems (crisis-prevention) (Campbell 1977).

Short-range controls, of insects and diseases at least, are largely chemical or mechanical in nature and as I said at the outset have been largely ineffective in resolving pest problems. This is not to say that they were not always necessary or achieved a valued goal. Implicit in the integrated protection process, however, is a more realistic evaluation of the necessity for short-range control.

Long-range control methods in forestry will be largely cultural or biological and their potential, uncovered by the methodical planning process of the integrated protection system, can be estimated by the kinds of models described. I must emphasize again that these glib statements on control potentials are based on the assumption that the basic ecological data necessary for selecting and implementing such controls either exists or is acquired during the system-building process.

In attempting to define the evolving concept of integrated pest management, I have coined a new term "Integrated Forest Protection Against Pests" which embraces integrated pest management as it is commonly defined. To do otherwise would seem to me to be like defining the chassis of an automobile without describing the motor--forest management is the driving force.

Why it is needed

Previously, I used the terms "crisis response" and "crisis prevention." Our history of pest control is 99.9 percent crisis response. In 1972 Waters stated: "The hard fact is that in spite of significant advances in pest control technology we have not really resolved a single major forest insect or disease problem in the United States." That statement is still true today.

Our obsession with the inappropriate, ineffective, and environmentally unacceptable techniques of agricultural pest management have caused us to ignore, or at least slight, the essential bases for sound pest management (i.e. --a thorough knowledge of pest ecology, of ecosystem interactions, evaluation of impact and forest stand dynamics) (Kibbee ed. 1976).

For many of our major pest problems sufficient information is available to design a forest protection system along the lines outlined previously. For various historical reasons, (political, organizational, scientific, ethical, etc.) this information is fragmented--there is little sense of focus or direction. Responsibilities are similarly fragmented. The process described previously, IFPAP, provides one blueprint for organizing historical material to represent the responses of pest-host systems for comparing possible management actions.

The increased complexity of forest management imposed by the Resources Planning Act as amended by the National Forest Management Act will demand a responsive system to provide meaningful input to forest planners and managers on the activities of pest organisms.

We need also a greater emphasis on preventive measures and our experience to date indicates that the process of creating a modular integrated protection system such as that described can provide us with much of the knowledge necessary to develop long-range protection. This comes about from the collation and synthesis of historical data permitting more precise definition of research needs.

It is my firm belief that an integrated program such as that described will enable us to work more efficiently and productively towards crisis prevention, and where crisis response is necessary, to make more rational decisions on the essentiality of treatment and the mode of treatment.

How It Might Be Implemented

I was undecided how to respond to this question. If we restrict ourselves to the technical implementation, then in the very near future we will have firm guidelines for implementation on at least four major pest systems--the Douglas-fir tussock moth, the mountain pine beetle in lodgepole pine, the gypsy moth, dwarf mistletoe and somewhat later, the southern pine beetle and perhaps the spruce budworm. All these follow roughly the format given as a definition, and I believe much of the technology will be transferrable to other pest/host systems such as vertebrates and regeneration.

I am most definitely NOT saying we will have brought these pests under management. However, we can have an orderly decisionmaking process that, if implemented and sustained will soon bring about preventive control in intensively managed forests and minimize the number of crises. None will be absolute--in no pest-host system do we have the depth of ecological knowledge to guarantee that. However, they will be properly planned, executed and evaluated simulation processes that will permit experimentation leading to operationally satisfactory pest management systems.

The barriers to effective implementation are less technological or scientific than they are political or organizational. This is an

extremely complex subject that I hope this colloquium will expose clearly for the guidance of the proposed subsequent studies. A few obvious issues inhibiting implementation are:

1) lack of uniform criteria and data acquisition systems for the various components of the system;

2) lack of uniform analysis and evaluation methods;

3) lack of integration between planning levels;

4) lack of a feedback or follow-up system, i.e., imprecise recognition of responsibility for action; and

5) lack of effective communication systems between agencies and institutions.

Most of these (and those omitted) could be resolved with a precise redefinition of responsibilities to accomplish the design accepted for implementation. Where jurisdiction crosses agency lines, firm committments must be secured to achieve the goals set, even to the point of surrendering some responsibility and authority.

I mentioned at the outset that I am an optimist. I believe a system developed along the lines described, with existing knowledge and technology, can do much to ameliorate our existing problems. More important, such a system plus a renewed, firmer commitment to the study of the basic science of ecology-forest and pest, will permit us to refine the preliminary gross models of the system to where we are in command and not our pests.

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NOT ANY GREEN THING...NOTES ON THE ECONOMICS OF FOREST PEST MANAGEMENT

Lloyd C. Irland

I have been asked to review a few points on the economics of forest pest management, including vegetation management. Space does not allow me to address vegetation management specifically, but I believe the principles involved are similar to those for insects. I have talked with Dr. Carlson to generally agree on sharing the tasks assigned to us by Bob Gale, but you will observe some overlap nonetheless. For further background, I refer you to the papers I am circulating separately.

I will summarize the importance of resource values in forest pest management decisions, will review the impact of Integrated Pest Management (IPM) on costs, and will summarize the cost-sharing issues that I deal with each year.

Importance of Resource Values

In evaluating the importance of resource values at stake, foresters often seem to foresee disastrous losses, as in the locust plagues visited on Egypt:

> ...they covered the face of the whole earth, so that the land was darkened; and they did eat every herb of the land, and all the fruit of the trees which the hail had left: and there remained not any green thing in the trees, or in the herbs of the field, through all the land of Egypt. (Exodus, 10:15)

Moses, of course, was the first successful IPM manager, since he convinced the Almighty to provide a west wind that blew every locust into the Red Sea.

In the absence of better predictive capacity for damage under no-control policies, we will continue to see forest insect problems depicted in these terms. To review resource values specifically, consider the spruce budworm. The major questions are: a) individual stand effects; b) regional effects on timber harvest; c) valuation of losses; and d) the social costs of pesticide use (Irland, 1977)

A. Individual Stand

Before outbreak, stand may be rated according to its probability of losses once it is infested. At onset of outbreak, ultimate losses with

and without control may not be predictable with enough accuracy to aid decisions (Irland, 1977, Mattson & Addy, 1975). And once an outbreak has occurred, the stand will go through a series of resource adjustments. Most losses will occur in the first 6 years. This will be followed by changing resource uses and the gradual recovery of the stand. The total time to regenerate a new merchantable stand is 50 to 60 years.

B. Regional Timber Harvest Level

Some pests, such as eastern spruce budworm, occur in outbreaks over such vast areas that they can affect the potential harvest level of an entire region. (Table 1). Where this is likely, the balance between current and prospective allowable harvests, with and without control, must be compared with wood requirements to sustain mills. The experience in Maine after 1912-1920 is well documented, and simulation models such as those used to produce Table 1 support this concept (Hazelton, 1979, Weed, 1977).

TABLE 1. - ECONOMIC IMPLICATIONS OF BUDWORM CONTROL, NEW BRUNSWICK 1952-76.

	1952 Level	1976 level no protection 1952-1976	1976 level with historical protection 1952-1976
Annual Harvest (MM cunits)	1,404	1,268	2,500
Annual Value Added ($ million)	143	128	416
Annual Wages ($ million)	63	43	128
Annual Man-yrs. employment	11,150	4,313	11,055
Total Forest Inventory (million cunits)	104	32	100

Source: Cabinet Committee on Economic Development, 1976, p. 189 (Baskerville Report).

Over time, budworm regulates the forest growing stock by removing mature trees that have stopped growing. The problem is that it does this in a periodic burst of eating rather than steadily, year by year.

In some areas today, existing mill capacity equals the sustained harvest based on today's inventory, before considering the impact of budworm losses. Where this occurs, there are several options:

1. reduce exports of roundwood;
2. increase imports of roundwood;
3. overhaul the mills to use another species;
4. accept losses of output and employment;
5. apply protection to attempt to sustain inventory and harvest.

Depending on the area economy, the pest in question, and the alternate sources of timber, some of these options may not actually be feasible.

C. Valuation of Losses

A number of technical and economic factors make it extremely difficult to value losses (Brown and Boster, 1978; Irland, 1977). Technical information on the precise pattern of physical changes in relating to value or processing cost may not be available. Dead trees may not be total losses, unless poor access makes it impossible to get to them in time. Where stands are partially killed, silvicultural considerations may require that the surviving green timber be taken as well, which dilutes efforts to salvage dead wood (Wade and Ward, 1975). Because of merchantibility limits, losses on the order of 5-8 cords per acre may be non-recoverable, but losses of 40-60 percent may effectively mean the total loss of the stand.

Market values may be misleading due to vertical intergration and concentration on buying and selling sides of the market, or due to predominance of government ownership. In principle, shadow prices could be derived, but unavailability of economically meaningful cost data makes this approach unpromising.

Where massive losses are possible, price changes introduce questions of consumers/producers surplus and may require assumptions about the nature of demand curves to allow price forecasts. I do not believe that sufficiently precise knowledge of demand in any reigon of North America exists to allow accurate predictions of price responses.

The objective of protection is to reduce economic losses caused by the damaging agent. For most forest pests, rough and ready applications of the economic threshold concept have been made. Frequently, we have deferred action until considerable tree damage has been sustained, which in practice, means two things:

First, much damage (decline in vigor, growth loss) has occurred that cannot be recovered by treatment (Stedinger, 1977). Second, penalty for tardy or unsuccessful control is far more serious, since affected stands have exhausted their resources of resistance and vigor and further damage may kill them.

D. Social Costs of Pesticide Use

Some experts believe that use of pesticides threatens resource values in the form of fish, birds, and beneficial insects. Others see potential danger to human health. And some members of the public see pesticide use as undesirable and irresponsible. All these facts create significant social costs of pesticide uses. I would argue against trying to measure these in dollars, though some economists are more venturesome in this regard. The unknown social costs, however, mean that a heavy burden of proof must be sustained before proceeding with massive chemical spray programs.

Impact of IPM on Costs

We know very little of the ultimate shape that will be taken by IPM for forest insect and vegetation management problems. I would hesitate to predict that better IPM will significantly reduce the costs of forest management and commercial wood production. I expect, however, that improved wood yields may result, and that cultural practices allied with IPM will support, and be supported by, the expected movements in timber prices and management intensity in the future. For the vast bulk of our forest resource which will never be intensively managed, however, application of IPM will simply amount to survey and dectection and salvage or abandonment of wood crops.

Several features can be expected to mark the future of IPM.

1. Improved survey and detection systems, coupled with better predictive capability for infestations and for damage with and without control. Stand dynamics models such as have been developed for Douglas-fir tussock moth and pine bark beetles are important here.

2. Development of effective cultural measures for reduction of stand vulnerability in advance of outbreaks. Better prognosis of insect problems in plantation monocultures will help avoid bitter surprises such as have been experienced in some areas of the South. Application of more intensive cultural measures for IPM will require improved logging equipment for partial cuts, improved access, and better silvicultural knowledge. In some areas, better markets for small-sized and low-grade wood will be needed.

3. Improved insecticides and application methods. Emphasis should be on biologically based materials (virus, Bt, fungi), but conventional chemicals should not be overlooked.

4. Improved impact and economic analysis techniques. For some pests, biological studies of impact are difficult to use for economic analysis. Further work in impact is required. Improved prediction is essential to better economic analysis, which is now based mostly on rule-of-thumb and scattered anecdotal evidence. It is striking that so little good economic analysis has been done on forest pest management, considering the controversies over spray projects, the sizable annual outlays, and the dramatic impact of pests on forest growth. Recent compendia on forest economics and policy, e.g. Clawson, Research in Forest Economics and Policy, have almost nothing to say on the economics of forest protection.

5. As local knowledge of forest types and site relationships improves, more sophisticated pest management will become possible. Determination of economic thresholds for individual stands will become possible. At present, it is virtually impossible to apply sensitive and detailed economic analysis to a one-million acre spray project.

6. Well-planned demonstration projects are required to assess the feasibility of intensive use of IPM methods; starting first, I would recommend, in high value stands such as parks or lakefront, no-spray buffers. Parasite releases, pheromone mass-trapping, individual tree hazard rating and management, and other techniques might be tested.

We all desire to minimize the use of chemical spraying in forestry, and we recognize that the forest is unlikely to be able to sustain continuous protection costs each year at the rates now common for some defoliators. However, we must recognize that a strategy that totally renounces pesticide use will have some special features.

1. It will emphasize short rotations and the holding of lowest possible growing stock levels, to reduce risk.

2. It may make the use of really intensive management systems impossible due to risk.

3. It may make use of partial cutting systems impossible due to enhanced susceptibility and risk of loss of the residual stand.

So far, little attention has been given to the true economic and silvicultural demands of forest management without pesticides. I see this as a high research priority.

Cost-Sharing Issues

The question of cost-sharing for forest pest management is high on everyone's list today. The status quo in this field is highly diverse among states, is poorly studied, and unsatisfactory to almost everyone. Political realities prevent attaining a degree of objectivity and uniformity that we all might desire.

I might outline the cost-sharing controversy briefly by summarizing the perspectives of four major actors: the distant philosopher, the local public official, the landowner, and the local resident in a forested area.

Philosophers

The person taking an unbiased, philosophical longterm view of forest pest management sees that pests are part of nature and feels that Man should adapt to their presence. He sees the rise and fall of industries as a broad historical pattern that it doesn't pay to fight. In the Olympian clarity of the atmosphere (say, in the new Executive Office Building), he sees that timber losses and mill shutdowns in Maine or New Mexico threaten no noticeable federal interest but are simply local problems. No secondary benefits. The yield losses are in the future, often many years, so at any reasonable discount rate they are worth little or nothing. If they would just manage the forest better the problem would go away. From this perspective, it is hard to see a federal interest in <u>any</u> insect or disease problem, except perhaps for quarantining any newly imported and dangerous bugs.

Local Public Officials

Local officials face a different set of constraints and values than the philosopher. They are legally responsible for forest protection, and are frequently tempted to assume the worst in their planning, because the consequences of error in that direction seem less serious. Since control costs are federally assisted, an unnecessary control project doesn't cost us much, but if we've underestimated the problem, the losses could be serious.

Small owners may clamor for protection, and if jobs are to be lost, it will be among our constituents, and not off on Mt. Olympus somewhere. Finally, it is also an American tendency to make a federal problem out of things that begin to get too big for local finances to handle.

Landowners

Large forest landowners tend to believe that their industry is so important that a public obligation to contribute to insect control

automatically exists. (It's a profit-and-loss economy; we'll take responsibility for the profits, thank you, but the public should help with the losses...). If losses prove serious, government will lose tax revenue, and should be willing to pay to prevent those losses. Where the insect is contagious or where properties are intimately interwoven, individualistic private action is unproductive, so government must step in (ignoring the possibility of private co-ops). Finally, industry forests provide many public benefits in the form of watershed protection and free recreation, for which owners are not compensated. When bugs threaten the forest, the public should be willing to help pay, in order to preserve the source of these benefits.

Local Residents

It may seem surprising, but local residents living near forests often do not connect the welfare of the forest with their own welfare. Frequently, they see forest protection as benefitting distant coupon-clippers on Long Island. Since they are the ones to breathe the insecticide, or eat the herbicide in their venison, they consider that they are being asked to shoulder the most obnoxious and dangerous costs of pesticide use themselves. Normally, they are not consulted about control plans.

Economists have three ways of analyzing cost-sharing problems, by reference to a number of concepts, such as:

1. ability to pay;
2. existence of externalities;
3. distribution of benefits;
4. justification for collective provision of service.

I have never seen these concepts effectively applied to the question of cost-sharing for forest pest management.

In connection with this, a data base on cost-sharing for forest pest policies by state and federal agencies is badly needed. An analysis of cost-shares employed in past USDA supported programs should be constructed and kept current.

Overview

What is needed, then, to make IPM a reality in managing forest pests in North America? First, better collaboration between manager, economists, and biologists to strengthen our ability to predict economic losses with and without control. Second, vigorous efforts to develop practical cultural measures and alternatives to pesticides. Combining these steps may produce a more realistic basis for appraising the true economic productivity of the forest resource. If this can be achieved, fewer plans will be made on the basis of unrealistic (no-bug) yield forecasts.

Finally, resolution of cost-sharing questions (including casualty provisions of tax laws), will help clarify responsibility for pest losses and may eliminate perverse incentives that now face managers and senior public officials.

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ECONOMICS OF FOREST PEST MANAGEMENT

Gerald A. Carlson

During the past two decades there have been relative price trends that have affected the mix of resources used in pest control. Prices of labor and land rose more rapidly than insecticides during the late 1950's and 1960's (table 1).

TABLE 1. RELATIVE PRICES OF PESTICIDES AND OTHER INPUTS

YEAR	FARM LAND	WAGE RATE	FERTILIZER	ENERGY	INSECTICIDES[1]	HERBICIDES
			(1967 = 100)			
1955	52	61	105	N/A	103*	59*
1960	68	74	103	N/A	112*	70*
1965	86	86	103	98	95	102
1970	117	128	88	104	122	100
1975	214	192	217	177	190	157
1976	244	210	185	187	190	250

SOURCE: AGRICULTURAL STATISTICS, 1977

* - ESTIMATED FROM DATA FROM U. S. TRADE COMMISSION, SYNTHETIC ORGANIC CHEMICALS.

1 - ORGANOCHLORINE INSECTICIDES (DDT), 2, 2, 4-D

More recently herbicide prices have risen rapidly relative to those for labor. Table 2 shows the rapid recent rise in cost per acre of forest insect treatments. These shifts encourage adjustment toward less expensive pest control resources. Following such price trends

may help project future economic problem areas in pest control.

The next section indicates some of the trends in integrated pest management that reflect some of the price changes in resources.

TABLE 2. MAINE FOREST SPRAY AREA AND COST HISTORY, 1954-1977

YEAR	ACRES SPRAYED	COST/A.	1967=100 COST INDEX
1954	20,000	1.54	96
1958	302,061	.78	49
1960	217,608	.97	61
1961	52,989	1.17	73
1963	479,015	1.06	66
1964	58,100	1.55	97
1967	92,162	1.60	100
1970	210,000	1.23	77
1972	500,000	2.62	164
1973	450,000	2.61	163
1974	420,000	2.33	146
1975	2,233,500	2.70	169
1976	3,500,000	2.43	152
1977 (EST)	922,000	3.25	203
1978	1,140,000	3.25	203

SOURCE: MAINE FOREST SERVICE

Economic Lessons and Trends to Learn from Agricultural Pest Management.

There is a trend toward more use of monitoring relative to direct pest control resources--traps, new diagnostic procedures for nematodes, soil insects, and many pathogens. Agriculture may be beginning to catch up with forestry in the use of sequential sampling.

There is an increase in use and evaluation of large-area control programs in agriculture (boll weevil eradication, spray cooperatives, abatement districts). Efforts by independent, adjacent landowners have often ignored the migrating patterns of pests. There are economies of size in monitoring, control, and evaluation. There are also diseconomies of size.

Pesticide firms, pest control consultants and other private firms are actively finding expanded roles in pest management. These firms offer pest monitoring services, less disruptive insecticides (microbials, low volume treatment, stickers and spreaders) and more accurate pest control equipment. Integrated pest management is not anti-pesticide. It proposes means of preventing pesticide resistant development and prolonging the economic life of existing pesticides.

A large part of integrated pest management (IPM) in agriculture has been directed at new information systems. Refinement of pesticide recommendations (dosage, timing, and type of material), establishment of treatment thresholds, and provision of warning systems are examples. Information is expensive; it has diminishing returns. Large homogeneous forests can afford to have better information than small ones.

New pesticide materials provide broader options in pest management. FIFRA and other use restrictions have not discouraged worldwide pesticide discovery. There are new synthetic pyrethroids, chitin inhibitors and microbial pesticides coming on the market to replace compounds removed from the market. These compounds may be less disruptive to beneficial insects and other non-target species.

Some of the major pest management lessons learned have come from mixing various agricultural scientists. Monitoring for disease, insect, nematode and weed problems concurrently can greatly reduce monitoring costs per unit of area. This helps keep a pest specialist employed for a full year. There are major interactions between insecticides, nematodocides, and herbicides. Breeding programs need to have information on the relative economic value of various pest resistant traits. Perhaps the proposed Forest Service studies which divide along discipline lines (weeds--other) should be reconsidered for these reasons.

There does not seem to be any trend of reduction in the value of major wildlife species or other environmental resources that may be affected by pesticide runoff. The demand for outdoor recreation

activities such as hunting, fishing, hiking, and camping has a large income expansion effect. Human health also has a large income effect relative to the income effect for food and fiber production.

Risk in Forest Pest Control.

One of the most serious resource allocation questions in the case of pest control is the extent of precautionary or insurance pesticide applications. Forest managers consider many of these applications as technically unnecessary. External costs of these treatments also point toward the need to reduce these applications.

Figure I shows the economic interpretation of why people rationally choose to take insurance pest control actions. A no-treatment strategy would lead to an A or B level of income and utility depending on a high or low pest infestation. Points C and D, with mean value E, are the comparable outcomes if a routine (insurance) protection strategy is followed. Even though no treatment, with an expected income of F, is higher than the expected income for regular treatment at E, risk adverse people will choose the regular treatment alternative because it gives higher expected utility. Only a risk neutral person would choose no treatment.

This type of analysis pertains to both public and private forest managers. It helps explain why public officials may be reticent in adopting more risky IPM approaches to pest control.

Uncertainties abound in the case of protecting a growing tree stock. A frequently proposed strategy is to apply pesticides or harvest early in the rotation to avoid long periods of pest exposure. The

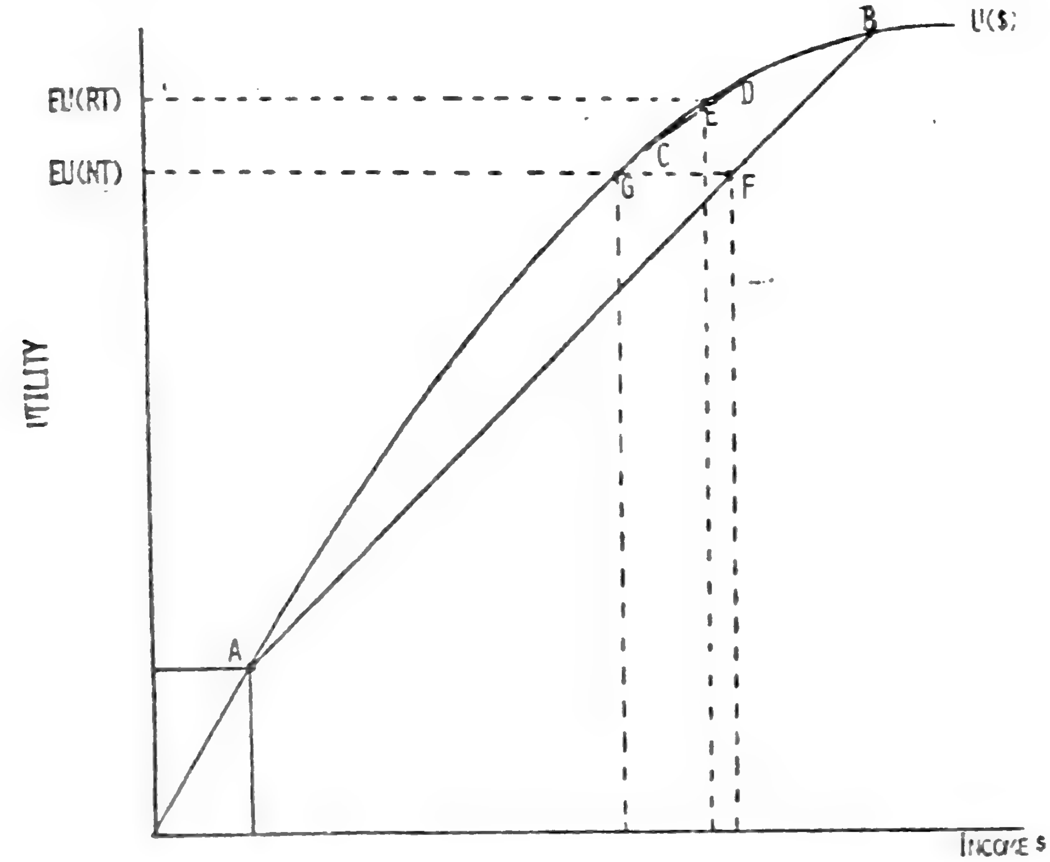

Figure 1. Utility of Income Showing the Effect of Risk Aversion on Choice Between Regular and No Pest Treatment

alternative is to let a pest infestation occur, allow for a decline in tree growth, and harvest when usual marginal gain and cost criteria apply to the post attack forest stand. This situation is depicted in figure 2. Forest growth is shown with a single major pest attack. Constant present value curves are also included. Given certain simplifying assumptions, optimal harvest date is given where forest growth rate equals marginal change in pest value (equal slopes). This could lead to optimal harvest at T_{25} for 10 percent opportunity cost, harvest at T_{60} for an 8 percent interest cost, or no tree production for the 10 percent plus additional initial costs of a herbicide treatment. 1/

The major uncertainties in the above problem setting have biological parameters that may need major research and policy attention. These include:

1. How long does high level defoliation need to occur to cause tree mortality or quality downgrade under various site and specie conditions?

2. What is the rate of growth of pest populations at highly suppressed levels? That is, how much research and monitoring needs to be directed at non-epidemic or non-outbreak forest conditions?

3. What are the probabilities of large pest in-migrations for various stand conditions?

4. What are the future technology prospects and resulting forest product prices of high level salvage operations?

5. Are there institutional arrangements such as cooperatives, forest insurance or protection contracts that effectively reduce risk?

The reduction of uncertainties can assist both policymakers and individual forest managers. The presence of large forest damage, possible external costs, and rising pest control resource costs should dictate more attention to these issues.

1/ Other results can also be derived. In particular, it will only pay to wait through destructive phases and regrowth if the rate of regrowth is faster than the compound interest rate.

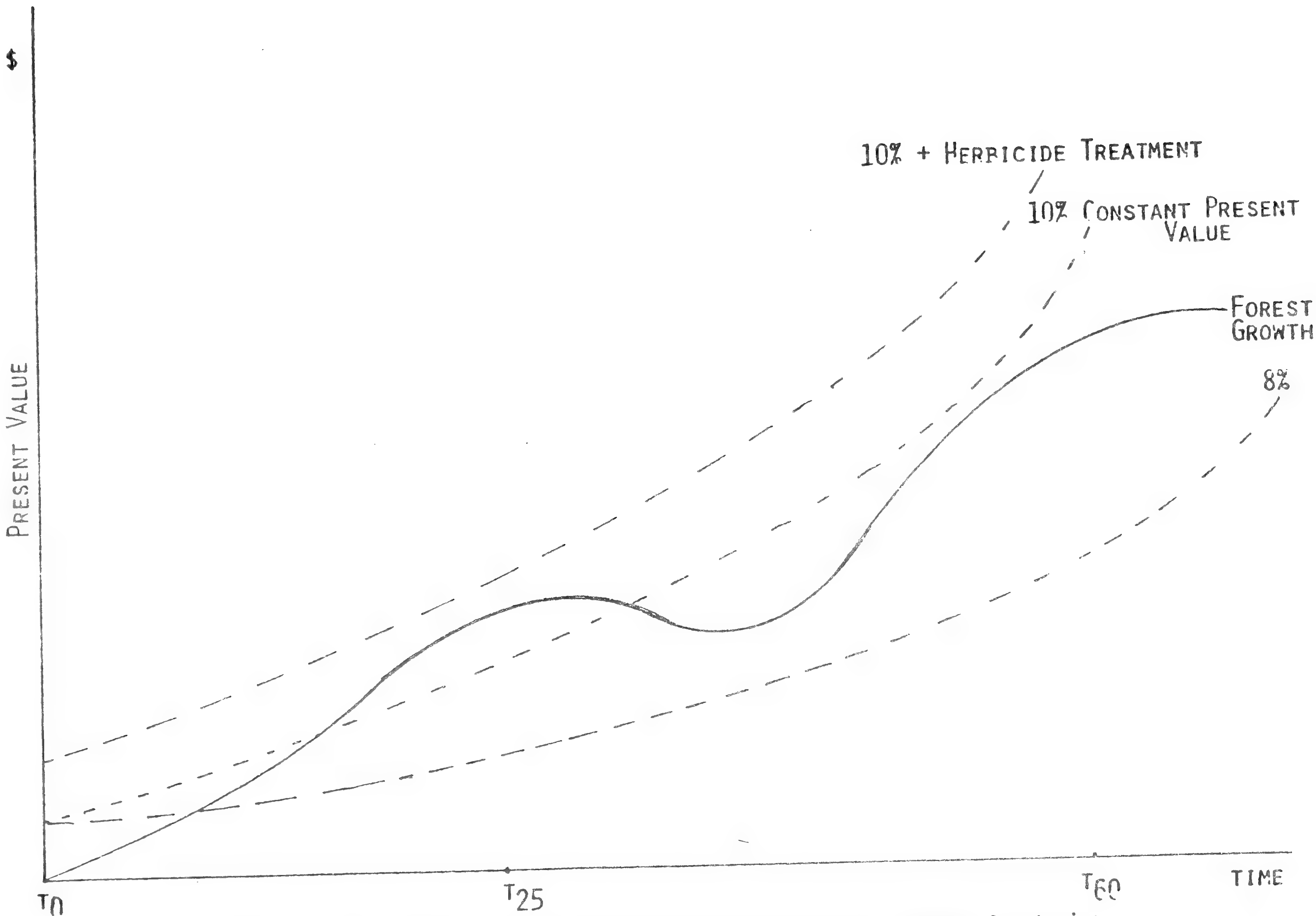

Figure 2. Forest Growth with Pest Defoliation and Various Harvest Strategies

ISSUES RELATED TO RESPONSE MODELS IN A DECISION SUPPORT SYSTEM

Albert R. Stage

Response models that predict effects of silvicultural activities on forests are vital components of forest management decisionmaking. Some issues related to response models are:

1) How and by whom should models be developed or maintained?

2) What should be their resolution?

3) What features of the forest should they describe?

4) What should be their relation to inventory procedures?

Answering these questions depends on understanding the context in which the response models are to be used.

The response models considered in this discussion are part of a process for supplying information about resource responses needed for scheduling forest management activities. Special emphasis is given to decisions concerning treatments that affect pest populations - either directly through pesticides or indirectly through the dynamic interactions among populations of hosts and pests. Implicit in this decision process is that a choice from among alternative schedules of activities will depend on comparison of expected consequences, i.e., from comparing the predictions of how the future would appear if each of the alternative activity schedules were to be adopted. When the system to which the activities are to be applied is a complex forest ecosystem, the manager needs extensive assistance to develop the predictions. The talents, information, and facilities for providing this assistance have been termed a decision support system. For example, such a decision support system for integrated forest protection against Douglas-fir tussock moth (Stark, this proceedings) was one of the results of the USDA Accelerated Douglas-fir Tussock Moth R&D Program.

The goal of the decision support system is to help the manager plan a schedule of activities, which, when followed, are expected to meet the specified goals of management within the limited resources available to the manager. For a silviculturist, the activities might include regeneration harvests, thinning, cleaning, release from competing vegetation, site preparation, planting and other cultural activities. The goals to be met might include production of timber products, enhancement of wildlife habitat, or maintenance of esthetic appearance, all within a given budget and work force.

The decision support system for forest management consists of procedures for five segments of the planning process. These segments, in sequence are:

1) Define range of treatments that are to be considered;

2) Inventory the resources that are to be considered;

3) Predict the consequences of performing the treatments on the resources;

4) Choose the schedule of actions that most closely meet the specified goals;

5) Monitor the actual results of the treatment.

Response models are the tools used for the central segment in which consequences are predicted. If the models are to be useful, they must be designed to be compatible with the inventory procedures that set the starting point for the predictions. The models must have sufficient resolution to discriminate among the treatments to be evaluated. And finally, the models must express consequences on scales that are easily interpreted when the schedule of actions is to be chosen.

The manager/decisionmaker plays a very important role in the design of a decision support system, and hence, of response models. Two tasks are inescapably required of the manager. First, he must define clearly what attributes of the future status of the ecosystem will directly influence his decision. To use a motion-picture analogy, the manager must specify whether he requires a slow-motion, telescopic panning of the landscape, or whether a time-lapse wide-angle view is required. More precisely, the resolution of prognoses of particular attributes on the scales of future time and space must be specified. If the attribute is timber yield, is the manager interested in working circle totals by decades, or only in average levels of productivity over a rotation? If his view of the future includes wildlife, how is it to be delineated? As numbers of animals, and if so, of what species? As density of nesting sites, or acres of habitat?

The second task required of the manager is to specify the range of treatments he is considering. In many cases, certain actions may be precluded by prior decisions concerning land use. Is herbicide application to be considered? Can precommercial thinning be included? What minimum volumes must be available to schedule a commercial thinning? The range of activities may be limited by prior decisions, by access, or by other externalities. The key feature of this segment is that more than one set of possible actions is proposed. Choice of the best schedule of activities follows comparison of consequences for each set of actions.

Each of these two tasks is, in itself, a decision to which the same process could be applied. This apparently infinite regression only illustrates the hierarchical nature of decisions that is inherent in all management planning.

At present, decision support systems in forest management have evolved in very informal ways. In particular, the development of response models has often been done without clear statements of how they could be used in tandem with field-feasible inventory procedures. Conversely, inventory procedures have been designed to describe current levels of the resource, with little emphasis on predicting consequences of treatment. For example, timber yield tables, which were an early form of response model, often demanded site classification procedures that were incompatible with the statistical sampling procedures used in forest inventory. In relation to the subsequent segment of the system, the yield tables contained information on only certain dimensions of the forest such as a few scales of merchantable volumes. Such scales, while useful for describing the current timber supply, were ineffective descriptors for linking to response models of other parts of the ecosystem such as the hydrologic or wildlife resources.

Response models have generally been developed for one tree species or type, or for one pest species independently of models for other species or types. Their development has generally been considered a research task. However, in a research environment, emphasis on innovation has tended to limit the comparability of predictions using models produced by different investigators. Yet, if these models are to be useful in a decision support system that allocates investment, comparability of assumptions, resolution and units of measure among the models is necessary. Obtaining or evaluating comparability among independently developed models is seldom given much attention. As a consequence, resource allocation and investment decisions are likely to be inefficient or ineffective.

Inventory methods also are difficult to apply if each species of tree or pest requires different measurements, methods and standards. Training is more expensive and errors are more common. Indeed, current pest survey methods are so variable, even for a single species that forecasts are chaotic.

A common difficulty in predicting future consequences arises when the decisions to be made depend on coupling independent models of different components of the ecosystem. All too often, apparently well-founded models of different, interacting components of ecosystems cannot be linked to display the full scope of treatment effects. For example, the linking of models of tree growth with insect population models of the Douglas-fir tussock moth showed

that outcomes of the combined models were very sensitive to certain variables linking the two models. However, until explicit linkage of the two components was attempted, need for, or interest in, studying these variables had not been identified. Hence, predicted consequences of pest management activities are not as definitive as would have been possible with a different allocation of research effort.

Investigators of ecosystem responses often express a reluctance to cast their knowledge in the form of models. Usually, their reluctance stems from their dissatisfaction with the present precision of the predictions that would be made. They would prefer to defer modeling until their knowledge is more definitive. Unfortunately, their lack of participation forces the decisions which must be made to be based on mental forecasts of outcomes. What the investigators fail to appreciate is that mental synthesis of imperfectly transmitted, incomplete representations of current knowledge is a poor substitute for a more formal model synthesis of that knowledge. Indeed, early synthesis of knowledge in model format can guide the allocation of research effort so that the overall reliability of predictions will be improved at a faster pace than otherwise.

In recent years, modeling techniques have advanced in resolution and sophistication. However, many of the current modeling efforts will find limited application in decision support systems because explicit interfacing with inventory methods, with resource allocation methods for choosing action schedules, and with the range of actions to be considered has not been planned to guide model development. Conversely, inventory systems are often designed without clear coordination with the data requirements of the models the inventory must initiate. We can do better!

ANALYSIS AND DECISIONMAKING MODELS FOR PEST MANAGEMENT

C. M. Newton

The basic decisionmaking sequence followed by pest managers is just like that practiced every day by both laymen and other types of professional managers. The primary difference between pest management and every day decisions is the intensity of analysis. The daily decision as to what time to awaken is rarely given more than a casual evaluation. Pest management decisions on the other hand frequently receive the benefit of thorough, highly structured deliberations. The usual justification for greater intensity of analysis is the often high cost associated with the consequences of an incorrect decision. An intensive detailed analysis is rarely appropriate unless both the possible consequences resulting from the alternative choices are significantly different, and the absolute cost or importance of at least one of the possible consequences is high. Without such a criterion, society would quickly be inundated with analyses. Furthermore, analysis regarding forest land implies a capability and intention to enact the decision, which in turn suggests a more intensive level of management than is currently practiced on many forested acres.

With increasing importance and sensitivity of the decisionmaking process, natural resource managers in general have followed the lead of business in the use of quantitative decisionmaking techniques. Many of the current quantitative procedures used by natural resource managers are understandably adaptations of techniques developed to address rather specific operational problems in business management. The objectives of this paper are to review some of these quantitative techniques, and to suggest criteria to be employed when planning model development. These objectives will hopefully be met by first reviewing the decisionmaking process within the context of pest management; then conducting a brief taxonomic evaluation of some of the more frequently used predictive techniques and decisionmaking models; and finally making a list of some considerations for model research and development programs. Since many specific models and procedures have been developed to address individual problems, it is beyond the scope of this paper to perform an item by item evaluation.

The Decisionmaking Process [1/]

The decisionmaking process, as I see it, may be conceived as the three interrelated activities of problem recognition, problem analysis, and problem solving. Figure 1 presents a schematic representation of the process.

1/ Much of this section has previously been presented by the author (Newton, C.M. 1973).

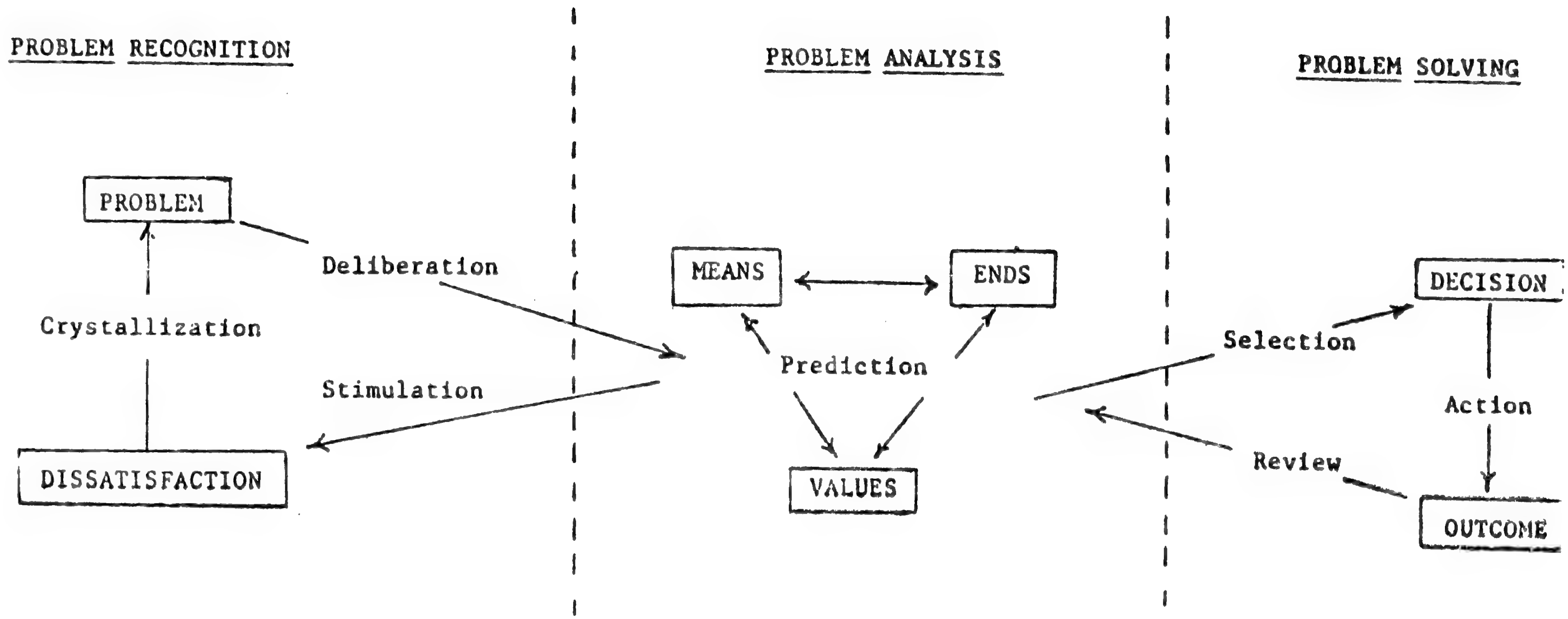

Figure 1. The Decision-Making Process (from Duerr et al. 1975).

The process begins when a problem is recognized via some stimulation to the manager. The stimulation may be rather obvious as would be the case when an insect outbreak is reported. It may also be largely intuitive, as when the manager feels uneasy because more and more harvested timber shows signs of recent insect attack. If the stimulation results in dissatisfaction, then the manager formulates a specific statement of the problem.

Deliberation brings the manager from problem recognition to problem analysis. Alternative "means" of solving the problem are listed. For each alternative action a set of possible outcomes or "ends" are identified. If appropriate, a probability function may accompany the outcome set to describe their relative likelihoods. Finally, each end is valued quantitatively and/or subjectively. Table 1 presents a matrix display of the valuation for a hypothetical infestation of southern pine beetle (Dendroctonous frontalis, Zimm.). The relative value assessments may have resulted from an indepth economic analysis or some other technique such as the application of utility theory.

For many pest management problems, the analysis activity frequently indicates that a potential solution has unknown outcomes, a poorly defined probability distribution, or questionable levels of valuation. This need for improved or more complete information provides the stimulus for yet another problem. Carrying this cycle to its final conclusion would mean then no decisions would be made without complete knowledge. Thus, management depends on applied research, which in turn is founded on basic research. At some level, the decision is made to terminate the analysis, with its supporting research, and accept the existing level of precision for the sake of expediency and economy.

A review of the situation is then made, and a particular alternative action is selected. This review should be done in a manner which reflects the goals of the organization. For a particularly complex set of alternatives, some quantitative technique may be employed to suggest the most suitable alternative. In terms of the original schematic (figure 1), this comparison of alternatives is just another problem definition. If the problem analysis technique results in the selection of an alternative, I refer to the technique employed as a decisionmaking model. Any other analysis would be termed a predictive technique. Predictive techniques provide the range of alternatives, outcome lists, probabilities, and relative values. In the example, table 1 summarizes the predictive results. The decisionmaking model of maximizing the long-term expected value suggests the second control strategy as being superior (its expected value equals 112.5).

Once the manager makes a decision, feedback in the system is provided for by his monitoring of the actual outcome. If the actual outcome differs from that anticipated, there is question as to whether or not

Table 1. Decision matrix for outcomes of hypothetical insect infestation.[1]

Decision alternatives	States of nature: Innocuous condition (Probability = 0.25)	States of nature: Outbreak condition (Probability = 0.75)
Salvage	1. High control costs because of small salvage areas. 2. Nominal loss of timber in new infestations. 3. Upper management satisfied. 4. Good public relations for an apparent job well done. Relative Value = 130	1. High control costs because of small salvage area. 2. Substantial loss of timber in new infestations. 3. Upper management understanding but disappointed because control cost incurred but still had outbreak. 4. Fair public relations because it is understood everything possible was done. Relative Value = 100
Cut, limb, and top	1. Low control cost. 2. Nominal loss of timber in new infestations. 3. Upper management pleased because lowest cost of control obtained without over-reaction. 4. Good public relations for an apparent job well done. Relative Value = 180	1. Low control cost. 2. Substantial loss of timber in new infestations. 3. Upper management displeased because strongest action not taken. 4. Mediocre public relations because strongest action not taken. Relative Value = 90
Do nothing	1. No control costs. 2. Slight loss of timber in new infestations. 3. Upper management very pleased because all control costs avoided. 4. Good public relations but a few complaints about inaction. Relative Value = 200	1. No control costs 2. Widespread loss of timber in new infestations. 3. Upper management very displeased because of inaction. 4. Poor public relations and numerous complaints about inaction. Relative Value = 0

[1]From Newton and Leuschner, 1975.

the problem has been adequately dealt with. Alternatives may be modified and reevaluated to incorporate the knowledge gained from the experience. This could in turn result in another entry into the problem analysis activity. The system has, of course, come full cycle.

Predictive Techniques

Predictive techniques, as I have defined them, are basically informational in nature. They are those quantitative methods which provide the information upon which the final selection of alternatives is based. Most economic analyses and inventory techniques would be included in this category. A decisionmaker who responds to a pest management problem is likely to want to know information regarding the pest population, the affected environment, the pest-environment interaction, the physical and social responses to alternative actions, the value of a successful problem solution, and the costs associated with the alternatives. In the absence of such information, pest managers rely on intuition and experience.

The rather popular quantitative techniques of simulation and sensitivity analysis could provide the pest manager with predictive information without the requisite of actual experience. Simulation is that process whereby a particular activity is quantitatively mimicked through the use of a series of mathematical relationships. Intrarelationships which possess a random element are allowed to vary accordingly to a hypothesized probability distribution. By entering inventory information, predictions are made at designated points in time. Thus by making repeated applications of the contemplated action, a set of system responses is accumulated which can then be used in lieu of actual experience for the eventual evaluation of alternatives.

In situations where a particular analytical technique requires information which is not currently known with certainty, an investigation of the consequences of an incorrect assumption is often suitable. A sensitivity analysis provides an indication of how the technique's results respond to changes in the assumed inventory or input variables. Sensitivity analysis can thus identify situations where additional experience is needed because the data precision is critical.

The design of a particular technique is obviously a function of the intended use. I cannot imagine the creation of an all encompassing, holistic model which adequately addresses all of the informational needs of a pest manager. All too often the construction and subsequent use of predictive techniques are not primarily a function of intended use, but rather are dictated by the availability of input data. The fallacy of this approach should be obvious. Within the arena of multiple-use management this logic tends to suggest data rich activities such as timber management at the cost of less documented operations such as dispersed recreation.

Decisionmaking Models

The outputs of predictive analysis are the input data for the decisionmaking analysis. The decisionmaking models include rather explicit statements of the goals and value systems of the manager, and presumably his organization. The result of this type of analysis is the suggestion to the manager of a single alternative, which he then chooses to either accept or reject. I would like to briefly examine, from a pest management viewpoint, the four decisionmaking models of linear programming, goal programming, discriminant analysis, and sequential analysis.

Linear programming is designed to recommend an optimal mix of activities or resources. Optimality is determined through the use of a mathematic objective function such as minimizing the cost plus loss function of control or minimizing the pest population density. Optimization is subject to several constraints which are also stated as mathematical functions. The constraints may be as simple as the maximum available budget for control or as complex as the acceptable legal and social limits for the application of pesticides. The implications of the technical assumptions of quantitative compatibility of the problem, linearity of the objective function and constraints, and mathematical additivity have been presented from a forest management viewpoint by Bell (1977). His presentation is lucid and very informative. I believe, as does Bell, that the biggest problem with the use of linear programming for natural resource management is the limitation that only one goal is to be optimized. Management for the good of the public is not easily stated as a single objective function. Quite often "public good" is expressed as a set of objective functions which are both qualitative and inherently conflicting.

Goal programming has been advocated as a solution to this problem of single objective definition. This technique accepts a set of goals or objective functions which are given equal consideration or are prioritized through the use of relative weights. Goals and constraints are expressed quantitatively. The recommended solution is that which comes as close as possible to satisfying all of the goals, implying no obvious simultaneous solution to all of the goals. Maximization of public good is thus assumed to occur when the cumulative disparity between the goals and their individual solutions is minimized.

I believe that pest management constitutes more than providing reactionary solutions to crisis infestations or outbreaks. The problem which initiates the analysis can be the periodic evaluation of preventive as well as reactionary actions. From this position, pest management can be considered to land-use planning whereby land areas are assigned to a particular management zone or category. Which hectares will be left alone, and which will receive the different types of control treatment?

If the land-use planning analogy is accepted, then I see a few difficulties with the use of either goal programming or linear programming as suitable decisionmaking models. First, neither method

normally makes an integral consideration of physical space. While the number of hectares to receive a particular control can easily be specified, contiguity of treatment areas cannot be guaranteed. One tempting approach might be to apply either of the two methods on a stand-by-stand or compartment-by-compartment basis resulting in a suggested action for each unit. This raises another problem. The units, be they compartments, stands, or one hectare cells, are assumed to be independent of each other. The management activities on one unit are thus considered not to affect the actions or outcomes of the adjacent units. This could easily lead to suboptimization of the management on the entire area while each separate unit is optimized. For example, a heavy pesticide application could be suggested in a small area which is totally surrounded by areas that were designated as developed recreation areas. The final difficulty is that when either method is applied on a regional basis, the output tends to be a table of hectares by treatment. The ability of the manager to transform the table into a spacially specific map remains to be seen.

Research by one of my graduate students, Ms. Debbie Barlow, is looking into the use of nontraditional quantitative approaches to the land use planning problem. The approach being taken is one which relies on discriminate analysis. First, the viable regional control strategies are defined. In close cooperation with the manager, a list of variables which are perceived as being important in the selection of a strategy is compiled. Zones are delineated on the basis of inventoried characteristics and their dimensions are registered through either cell or polygon digitization. Land areas where the best strategies are obvious are then identified by management. Discriminate analysis is then applied to these "knowns" to select pertinent variables and to identify their interrelationships as they result in specific solutions. Regionalization constraints are imposed to address the contiguity and independence problems. The final discrimination function is then applied to the entire region through the use of computer mapping techniques to suggest a final map of location specific strategies. This technique is not an optimization model, but rather one which tries to take advantage of qualitative as well as quantitative managerial experience. While some technical difficulties remain to be resolved, I believe this type of approach has definite promise in pest management decisionmaking.

The above tree decisionmaking models tend to be single phase in nature. They do not specifically include the alternative of collecting additional information via research or inventory efforts. In sequential analysis, all of the control strategies are considered against the option of postponement with subsequent terminal action. To evaluate whether or not to postpone control action requires the assessment of the probable value of the added information. Tables 2 through 5 present the information required for the use of sequential analysis in a hypothesized gypsy moth, Lymantria dispar (L.), control problem (Talerico et al, 1978).

Table 2. Conditional probabilities for the actual state given the survey indication.

Survey indication	Actual outcome: Innocuous state	Actual outcome: Outbreak state
Innocuous state	0.87	0.13
Outbreak state	.27	.76

Table 3. Historic probabilities of defoliation levels, given the egg-mass trend.

Condition indicated by egg-mass trend	>50 percent defoliation	≤50 percent defoliation
Innocuous	0.11	0.89
Outbreak	.39	.61

Table 4. Probabilities of defoliation given the survey results.

Survey indication	>50 percent defoliation	≤50 percent defoliation
Innocuous state	0.15 = (.87) (.11) + (.13) (.39)	0.85 = (.87) (.89) + (.13) (.61)
Outbreak state	0.32 = (.24) (.11) + (.76) (.39)	0.68 = (.24) (.89) + (.76) (.61)

Table 5. Expected costs associated with the decision to conduct a survey.

C₁—No control			C₂—Air spraying			C₃—Ground spraying		
Branch		EC	Branch		EC	Branch		EC
$S_1C_1d_1$	4.150×.32=	1.328	$S_1C_2d_1$	4.850×.05=	242	$S_1C_3d_1$	4,750×.11=	522
$S_1C_1d_1$	150×.68=	102	$S_1C_2d_2$	850×.95=	808	$S_1C_3d_2$	750×.89=	668
		$1.430			$1,050			$1,190
$S_2C_1d_1$	4,150×.15=	622	$S_2C_2d_1$	4,850×.02=	97	$S_2C_3d_1$	4,750×.05=	238
$S_2C_1d_2$	150×.85=	128	$S_2C_2d_2$	850×.98=	833	$S_2C_3d_2$	750×.95=	712
		$ 750			$ 930			$ 950

Figure 2 summarizes the information in the form of a decision tree. In this example, the minimum expected cost criterion results in the recommendation to adopt the second control strategy without the advantage of conducting an egg-mass survey.

The physical construction of a decision tree is easily understood. On the other hand, for many, if not most, pest management decisions, the assignment of values and probabilities to all of the decision-tree branches tends to be confusing. This assignment is accomplished by starting at each final outcome and working toward the origin. Values may be quantitative, as with dollars, or include more qualitative aspects through the use of utility theory. Bayesian statistics provide the theoretical foundation for the probability distribution. For additional information regarding techniques, Valentine, et al (1976) make a more detailed presentation of decision trees in pest management decisionmaking.

The basic rationale for the use of sequential analysis in pest management decisions is an assumed advantage which comes from the ability to continue sampling where the control selection involves large risks relative to those with the added information. Of course, the time and economic constraints associated with several small inquiries versus one large investigation may preclude sequential analysis. However, with the high environmental interest being shown in pest management control strategies, I believe that more and more decisions will be subjected to sequential analysis techniques.

Discussion

I would like to conclude this presentation by making four observations regarding research and development programs for problem analysis methods. First, it is my belief that one of the most valuable products of quantitative analysis techniques is the introduction of documentation and consistency into the decisionmaking process. The very action of writing down managerial thoughts, assumptions, values, and selection criteria is an act of responsibility and commitment, an aid to logical thought development, and a focus for discussion with subordinates, peers, and supervisors. Furthermore, it represents basic recordkeeping for future evaluation of strategy responses, and provides organization consistency when there might be managerial turnover.

The second point which I would like to make deals with simplicity. Predictive techniques tend to be quite sophisticated and rather esoteric as they become more accurate and precise. Once the conceptual approach is understood and accepted, managerial endorsement is expected. Decisionmaking models, since they suggest specific managerial strategies, do not often receive such quick acceptance. Regardless how sophisticated the model, it is my feeling that for it to be an effective component in the decisionmaking process, it must be thoroughly understood. In

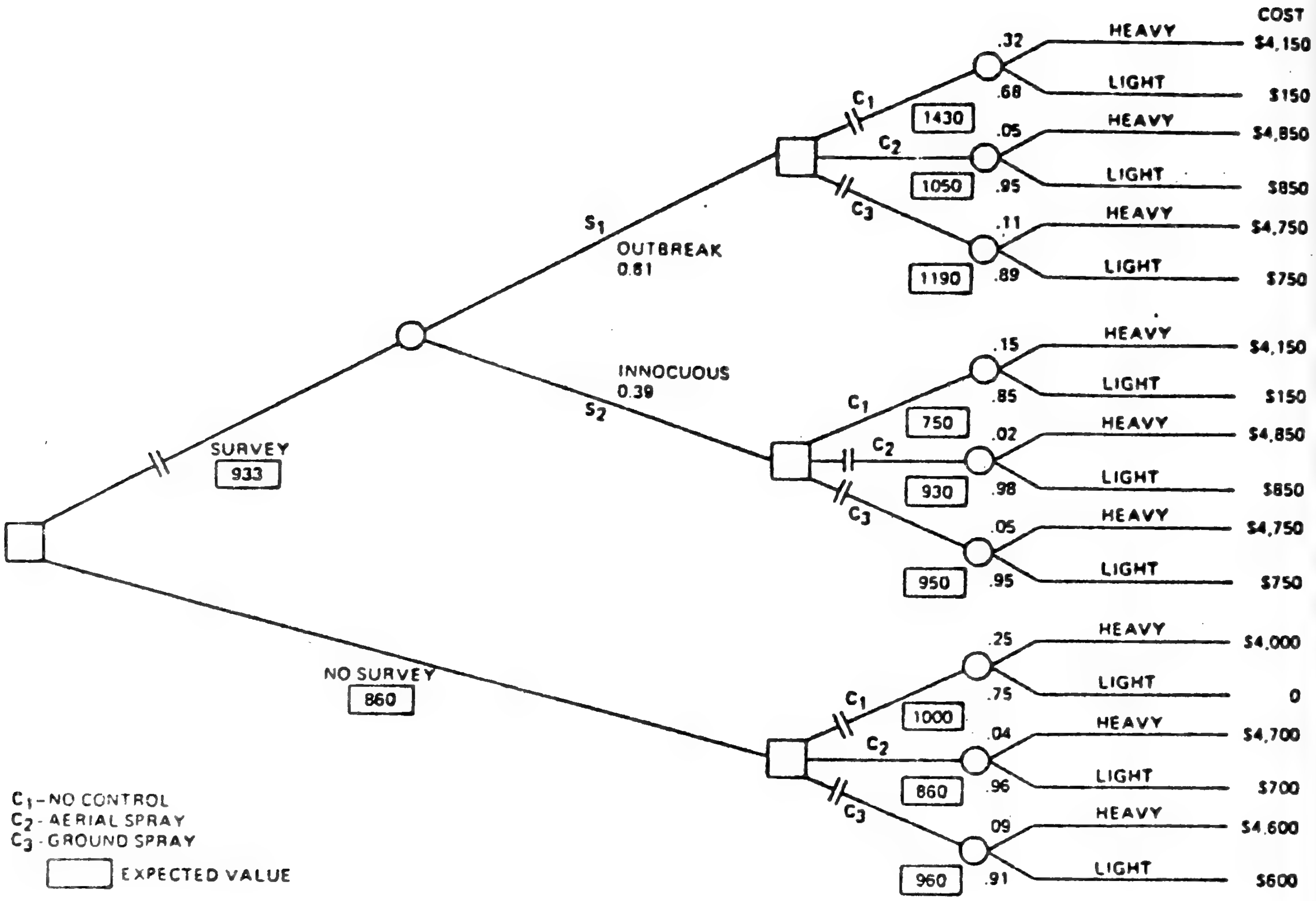

Figure 2. A decision tree modified to include the value of added information.

that regard, I would urge developers of decisionmaking models to continuously weigh the returns of increased sophistication against simplicity in understanding and use.

Another point to be considered is the issue of existing inventory and methodology. While the situation where the manager has a tool for which a problem is sought should be avoided, we shouldn't do that at the cost of innovative adaptations of existing knowledge. There are more inventory data and analytical techniques available than we think. With the increasing costs of data collection and system development, there is an accompanying increase in the potential benefits from not being scientifically or operationally myoptic. Involving multi-discipline scientists and managers with the problems of pest management should be strongly encouraged.

The last point for discussion which I would like to present addresses the issue of application. Research and development of analytical procedures should be concentrated on techniques which are likely to receive widespread application, or which address truly crucial natural resource management problems. We cannot afford the cost or time to formulate, calibrate, and validate techniques specific to every pest-environment combination. We should not lose sight of the fact that the entire research and development activity should be cost effective.

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EVALUATION OF FOREST PEST MANAGEMENT PROGRAM

The Study Approach

Robert D. Gale

Introduction

Dr. Cutler has asked the Chief to initiate a thorough evaluation of the Forest Service's pest management program. The purpose of the study is to establish and examine the rationale for our present program direction and make adjustments where appropriate.

The Forest Service has concluded that an evaluation of the pest management program could best be carried out using two separate studies. One study will address the insect and disease aspects of pest management. Under this study, vegetative management practices will be examined as they pertain to insect and disease problems. The second study will address vegetation management practices as they relate to weed control, vegetative production, and plant competition.

The following sections contain a proposed study outline to be used to develop a more detailed study plan for each study, and an explanation of the procedure to be used in carrying out the study.

Procedure for proceeding with the Forest Pest Management Evaluation

Two separate studies running concurrently will be undertaken. One study will evaluate the insect and disease pest programs and the other will evaluate vegetative management programs which are aimed at controlling vegetative growth.

Each study will be conducted by a contracting organization. A request for bids will be developed by Policy Analysis and circulated by appropriate procedures. Bid selection will be handled through the normal process with a review board and supervision from the contracting staff. Once a contractor has been selected for each study a detailed contract will be developed and agreed upon. Policy Analysis will be responsible for development, coordination, and administration of the contracts.

Objective

The objective is to evaluate the operating procedures of the Forest Service pest management programs and their interrelationships. Particular attention will be given to the operation of the "integrated pest management" concept.

Scope

The studies will be national in scope and address all three Forest Service program areas which have pest management responsibilities: 1) National Forest Systems; 2) State and Private Forestry; and 3) Research.

Outline for Proposed Studies

Each study conducted under Phase I and II would produce 2 reports: one dealing with insect and disease pests, the other with vegetative pests.

Phase I. -- Development of Program Background

A. Programs and activities to examine

- NFS
- S&PF
- Research
- Other Federal
- PUCC

their role and function

B. Review pest literature -- specific to evaluation and integration

C. Examine present policy

1. Its implications
2. Adequacy

D. Examine the trends in pest management practices and research -- construct a Regional list of types of treatment and their purpose (Consider 1, through 6. below)

1. Chemical
2. Biological
3. Silviculture
4. Fire
5. Mechanical
6. Prevention

E. Develop budget information -- relative to Regional, National and cost sharing pest programs.

F. Issue Identification

Develop a list and discuss current pest management issues.

Phase II.-- <u>Analysis</u>

A. <u>Evaluate present program management</u>

1. Decisionmaking -- strategies, procedures, and delegation of authority
2. Training and adequacy of personnel
3. Coordination within the FS, with other agencies, and various levels of government
4. Public involvement - how used and when
5. Research - adequacy and application

B. <u>Review and evaluate program considerations and implications of:</u>

1. Environmental impacts
2. Social impacts
3. Economic analysis

} Case studies

C. <u>Develop alternative management strategies</u> - review IPM discussion models and results of evaluations to date

Phase III <u>Final Report</u>

A. <u>Summarize findings</u> - from Phase I and II

B. <u>Make recommendations</u> - for program improvement

Current Management Issues

Everett Towle - Chairman

The issues listed below are the result of a panel discussion with audience participation.

1. What should be the FS role in EPA's registration process?
2. How should we communicate with the control agent producing industries?
3. What should be the priority for developing non-toxic chemicals?
4. What is the role of EPA vis-a-vis the FS in pest management?
5. How might we assess the public benefits of developing and registering a new control product prior to its undertaking?
6. We need to recognize that an organism is a pest only when it significantly interferes with forest management goals.
7. How pest prevention-oriented is the FS and how prevention-oriented should we be?
8. Pest management data collection need to be oriented toward discovering pest problems rather than only describing known problems.
9. Has the FS adequate follow-up on pest treatments?
10. To what degree have FIDM analyzed the effectiveness of control methods?
11. Are rodent pest problems given adequate consideration within the FS organization?
12. There is a need to strenghthen FS-EPA relations at the working level.
13. Several barriers exist in further implementing the integrated pest management (IPM) concept:

    a) lack of information,
    b) lack of appropriate data,
    c) insufficient analysis,
    d) insufficient planning,
    e) definition of responsibilities,
    f) communications.

14. What is the impact of wilderness on IPM?
15. What is the role of functional program staffers in pest management?
16. Is the present FS organization conducive to good pest management?
17. Does the present funding process for pest programs hamper implementation of IPM?
18. Should the concern be IPM or IFPAP (Integrated Forest Protection Against Pests)? Note, see R. Stark's paper.
19. Should control projects be funded for the life of the project as opposed to annually?
20. What intensity of forest management is required in order to practice IPM?
21. To what degree have site, stand inventory, and other basic resource management data included information on pests or been related to major pest problems?

22. Do present procedures hinder timeliness in attacking pest?
23. Are we properly handling uncertainties in pest management?
24. How are the various research efforts in pest management coordinated?
25. Is research providing the needed information for better pest management programs and decisions?
26. Is the precision of present pest models appropriate for the decisions which are made?
27. Does FS have appropriate pest management skills?
28. Are management practices recognizing pest management opportunities?
29. Should ecological relationships be given more consideration in routine management practices, e.g. right-of-way management ?
30. Do we adequately understand and recognize the beneficial role of organisms and vegetation in the forest ecosystem (including pests)?
31. To what degree have FIDR and FIDM activities been oriented to the fundamental ecological problems of forest stand and pest interactions?
32. To what degree has TM (or other resources management group) analyzed the effect of their activities on the pest situation?
33. To what degree has forest research in general addressed itself to the ecology of forest stands which includes the natural fluctuations of organisms capable of becoming pests?
34. How can technology transfer be improved?
35. How should pest management be related to the NFMA?
36. What is and should be the federal role in solving private land pest problems?

The Study Approach presented above is a first approximation of how the Forest Service intends to carry out and evaluate its pest management programs. The study outline is intended only as a suggested guide for potential contract bidders. Bidders will be required to submit a detailed study plan. These plans will be a primary factor in selecting a contractor.

At this time we welcome your questions and comments.